# VARIATION AND CORRELATION IN THE INFLORESCENCE OF MANFREDA VIRGINICA

J. ARTHUR HARRIS

*Head, Department of Botany, University of Minnesota*
*Formerly Botanical Assistant, Missouri Botanical Garden*

## I. Introduction

The purpose of this paper, which is one of a series on the general problem of the physiology of fertility in plants, is to present the results of a biometric study of variation and correlation in the inflorescences of *Manfreda virginica.*

This study was planned, the materials collected, and practically all the tabulations made at the Missouri Botanical Garden in 1906 and 1907.[1] The calculations were, in large part, carried out in the Biometric Laboratory at University College, London, in 1908. The long delay in completing the manuscript for publication has been in part due to pressure of other work and in part to an effort to secure formulae to deal more effectively with certain phases of the problem.

The points to be especially considered are:—

1. The variability and correlation of the same species when growing in different habitats.

2. The correlation between the number of flowers produced and the number of capsules developing, and between the number of flowers and capsules produced and the number of seeds developing.

3. The relationship between position of the flower on the inflorescence and fruit production.

4. The correlation between position of the flower on the inflorescence and the number of seeds per locule and per fruit.

5. The correlation between the position of the fruit on the inflorescence and the number of seeds per locule and per fruit.

6. The correlation between the number of seeds in the 3 locules of the fruit.

[1] The initial stages of the work were aided by a grant from the American Association for the Advancement of Science.

## II. Materials

The inflorescence of *M. virginica* is a favorable subject for work on the problem of fertility. Since all the flowers are arranged on a single axis, it is easy to consider the influence of position on the inflorescence upon the chances of development of the fruit and upon the characteristics of the matured fruit. The flowers which fail to produce fruits leave a conspicuous scar, so that the number of flowers produced may be accurately determined. The ripened seeds have a fine black color and are easily counted. Unfortunately it is impossible to determine the number of ovules formed. The trimerous nature of the fruit makes possible the consideration of certain problems concerning the interrelationship of numbers of seeds per locule.

Collections of material were taken from 2 different localities. The first was the more open woods at Meramec Highlands, near St. Louis. The second was the edge of the limestone cliffs along the Mississippi River, south of Jefferson Barracks, Mo.

In the absence of quantitative criteria no attempt will be made to distinguish in any precise way between the conditions for plant growth in these 2 habitats. The general impression conveyed by an examination of the two habitats was that growth at Meramec Highlands was much more luxuriant than that on the crests of the cliffs south of Jefferson Barracks.

The countings made comprise the following:—

1. Number of flowers per inflorescence ($f$).
2. Number of capsules matured per inflorescence ($c$).
3. The actual position of the capsule on the inflorescence ($p$). This is the position of the flower measured from the proximal end of the inflorescence. Thus the position of the first flower is 1, while that of the terminal flower is measured by the number of flowers produced on the inflorescences.
4. Relative position of the capsule ($r$). This measures the position of the individual capsule in the series produced by an inflorescence. Thus the relative position of the lowermost capsule will be 1, whatever the position of the flower which produced it, while that of the most distal capsule will be the same as the number of capsules produced by the inflorescence in question.

5. Number of seeds per locule ($s$).

The symbols in parentheses are those used to designate the several characters in the formulae.

The heavy work of counting the number of seeds per locule was carried out in only 1100 inflorescences or 18774 locules. Number of flowers and number of capsules was determined in a larger number of inflorescences, 3425 in all.

For convenience of reference the series of material are designated as follows:—

I. Three hundred inflorescences, Meramec Highlands, 1906. Seeds counted.

II. Two hundred fifty inflorescences, below Jefferson Barracks, 1906. Seeds counted.

III. One thousand inflorescences, below Jefferson Barracks, 1906. Flowers and fruits only counted.

IV. Three hundred inflorescences, Meramec Highlands, 1907. Seeds counted.

V. Three hundred five inflorescences, Meramec Highlands, 1907. Flowers and fruits only counted.

VI. Two hundred fifty inflorescences, below Jefferson Barracks, 1907. Seeds counted.

VII. One thousand twenty inflorescences, below Jefferson Barracks, 1907. Flowers and fruits only counted.

In studies involving only the number of flowers and number of fruits per inflorescence series II and III can be treated together; series IV can be combined with series V; and series VI added to series VII for the purpose of securing larger and smoother distributions. In respect to these characters series IV and V and series VI and VII should show only the differences due to random sampling, since practically all the material for each of the pairs was taken at one time and a subsample was drawn at random for the seed countings.

The lot of material from the Jefferson Barracks locality for 1907 is not strictly comparable with that for 1906 in one respect. The plants from which the countings of the number of seeds per locule were made in 1906 were collected all along the bluffs from Jefferson Barracks to a point above Cliff Cave. In 1907 the material from which the countings of seed number were made was taken

TABLE I

FREQUENCY DISTRIBUTION OF NUMBER OF FLOWERS PER INFLORESCENCE WITH TOTAL NUMBER OF FRUITS AND SEEDS PRODUCED BY EACH CLASS OF INFLORESCENCE IN 4 SERIES IN WHICH NUMBER OF SEEDS PER LOCULE WAS DETERMINED

| Flowers | J. B. 1906 | | | J. B. 1907 | | | M. H. 1906 | | | M. H. 1907 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | f | Fruits | Seeds | f | Fruits | Seeds | f | Fruits | Seeds | f | Fruits | Seeds |
| 2 | 1 | 1 | 47 | — | — | — | — | — | — | — | — | — |
| 6 | 1 | 2 | 58 | — | — | — | — | — | — | — | — | — |
| 7 | 1 | 4 | 148 | — | — | — | — | — | — | 1 | 1 | 43 |
| 8 | — | — | — | — | — | — | — | — | — | 1 | 2 | 73 |
| 9 | 1 | 2 | 67 | — | — | — | 1 | 2 | 82 | 1 | 1 | 27 |
| 10 | — | — | — | 1 | 7 | 85 | — | — | — | — | — | — |
| 11 | 2 | 6 | 193 | — | — | — | — | — | — | 1 | 7 | 66 |
| 12 | 3 | 8 | 220 | — | — | — | 1 | 3 | 154 | — | — | — |
| 13 | 1 | 2 | 56 | 2 | 4 | 138 | 2 | 6 | 163 | 4 | 13 | 291 |
| 14 | 7 | 20 | 593 | 5 | 13 | 452 | 2 | 5 | 147 | — | — | — |
| 15 | 8 | 21 | 664 | 2 | 6 | 323 | 1 | 4 | 156 | 6 | 21 | 769 |
| 16 | 9 | 29 | 960 | 6 | 24 | 807 | 2 | 7 | 221 | 7 | 21 | 917 |
| 17 | 15 | 37 | 1141 | 11 | 50 | 1681 | 4 | 14 | 658 | 6 | 21 | 778 |
| 18 | 12 | 43 | 1335 | 12 | 39 | 1511 | 6 | 26 | 1152 | 10 | 39 | 1640 |
| 19 | 17 | 60 | 1435 | 6 | 26 | 941 | 8 | 35 | 1505 | 16 | 59 | 2552 |
| 20 | 15 | 64 | 1676 | 11 | 43 | 1400 | 10 | 40 | 1452 | 12 | 47 | 1557 |
| 21 | 25 | 104 | 2764 | 6 | 24 | 686 | 14 | 59 | 2441 | 11 | 50 | 2012 |
| 22 | 18 | 79 | 2291 | 14 | 65 | 2389 | 10 | 42 | 1559 | 19 | 79 | 3279 |
| 23 | 12 | 51 | 1196 | 18 | 93 | 2918 | 7 | 36 | 1443 | 4 | 15 | 655 |
| 24 | 8 | 33 | 1077 | 14 | 68 | 2118 | 12 | 65 | 2612 | 13 | 73 | 2765 |
| 25 | 14 | 60 | 2003 | 15 | 82 | 2320 | 13 | 75 | 3071 | 15 | 79 | 2752 |
| 26 | 9 | 53 | 1469 | 11 | 62 | 2152 | 15 | 88 | 3722 | 16 | 86 | 3413 |
| 27 | 11 | 45 | 1654 | 14 | 74 | 2320 | 18 | 124 | 5353 | 16 | 83 | 2799 |
| 28 | 6 | 23 | 462 | 7 | 33 | 1067 | 17 | 103 | 4365 | 14 | 78 | 3339 |
| 29 | 7 | 37 | 878 | 5 | 30 | 1038 | 11 | 57 | 2399 | 13 | 80 | 2829 |
| 30 | 6 | 30 | 1234 | 7 | 44 | 1440 | 13 | 90 | 3819 | 9 | 60 | 2175 |
| 31 | 1 | 4 | 147 | 6 | 30 | 1026 | 18 | 128 | 5109 | 14 | 94 | 2942 |
| 32 | 6 | 37 | 1570 | 8 | 54 | 1852 | 6 | 42 | 1840 | 14 | 84 | 3419 |
| 33 | 4 | 22 | 767 | 9 | 61 | 1890 | 16 | 129 | 5237 | 7 | 47 | 1621 |
| 34 | 5 | 44 | 1628 | 9 | 65 | 2059 | 12 | 114 | 5059 | 13 | 92 | 3932 |
| 35 | 4 | 26 | 1084 | 12 | 77 | 2640 | 17 | 127 | 4510 | 10 | 83 | 3426 |
| 36 | 6 | 39 | 1584 | 5 | 28 | 938 | 9 | 73 | 2859 | 6 | 48 | 1536 |
| 37 | 2 | 16 | 462 | 6 | 51 | 1310 | 7 | 57 | 2343 | 6 | 47 | 1854 |
| 38 | 4 | 27 | 894 | 2 | 18 | 762 | 3 | 20 | 891 | 4 | 33 | 1292 |
| 39 | 1 | 7 | 263 | 4 | 28 | 903 | 5 | 41 | 1556 | 5 | 55 | 2152 |
| 40 | 1 | 8 | 345 | 3 | 17 | 607 | 6 | 50 | 2436 | 5 | 44 | 1715 |
| 41 | 1 | 10 | 227 | 3 | 25 | 684 | 3 | 31 | 1183 | 4 | 32 | 1134 |
| 42 | 1 | 11 | 355 | 3 | 25 | 938 | 7 | 70 | 3027 | 3 | 27 | 906 |
| 43 | 2 | 17 | 662 | 2 | 31 | 828 | 1 | 9 | 360 | 3 | 28 | 1113 |
| 44 | — | — | — | 3 | 17 | 609 | 2 | 13 | 510 | 4 | 32 | 1592 |
| 45 | 1 | 10 | 222 | 3 | 30 | 692 | 5 | 55 | 2345 | 1 | 8 | 428 |
| 46 | — | — | — | 3 | 32 | 1318 | 3 | 33 | 1251 | 1 | 13 | 453 |
| 47 | 1 | 16 | 454 | 1 | 10 | 356 | 1 | 9 | 256 | — | — | — |
| 48 | — | — | — | — | — | — | 5 | 47 | 2028 | — | — | — |
| 49 | — | — | — | — | — | — | 1 | 7 | 337 | — | — | — |
| 50 | 1 | 12 | 326 | — | — | — | — | — | — | — | — | — |
| 51 | — | — | — | — | — | — | — | — | — | 2 | 22 | 1188 |
| 52 | — | — | — | — | — | — | — | — | — | — | — | — |
| 53 | — | — | — | — | — | — | 1 | 12 | 388 | 1 | 13 | 465 |
| 54 | — | — | — | — | — | — | 3 | 41 | 2150 | — | — | — |
| 55 | — | — | — | — | — | — | 2 | 28 | 1178 | — | — | — |
| 60 | — | — | — | 1 | 6 | 195 | — | — | — | — | — | — |
| 61 | — | — | — | — | — | — | — | — | — | 2 | 20 | 655 |

entirely from the vicinity of Cliff Cave. The 1000 stalks taken in 1906 for countings of flowers and fruits only and the entire series of 1270 inflorescences taken in 1907 are therefore directly comparable as samples of the same species from the same locality for 2 years.

## III. Presentation and Analysis of Data

### I. TYPE AND VARIATION IN DIFFERENT HABITATS

In this section we have to consider the frequency distributions of number of flowers and fruits per inflorescence, and the number of seeds matured per locule and per fruit.

In doing this we shall hope to replace the impression of chaotic disorder which must be the result of mere inspection in the field by a definite mental picture of the orderliness which prevails in the frequencies of the numbers of flowers and fruits, in the position of insertion of the fruits, and in the number of seeds per locule and per fruit.

The frequency distribution of number of flowers per inflorescence in the 4 series in which the number of seeds was determined is shown in table I.[1] For the 3 other series, in which flowers and fruits only were counted, the reader must consult table II.

Because of the wide range of variation in number of flowers per inflorescence, very irregular graphs are obtained if the ungrouped frequencies are plotted. Grouping in classes of 3-units range and reducing to percentage frequencies we have the distributions for the two habitats represented in fig. 1 for 1906 and in fig. 2 for 1907. In 1906 the results for Meramec Highlands (N = 300) and Jefferson Barracks (N = 1250) are not in good agreement. The distribution for Meramec Highlands is particularly irregular, but this is doubtless due in large part to the fact that this series comprises only 300 inflorescences—less than one quarter the number from Jefferson Barracks. In 1907 the distributions represent 605 inflorescences for Meramec Highlands and 1270 for Jefferson Barracks, and are in much closer agreement.

[1] The frequencies of inflorescences with varying numbers of flowers are alone required here. The total fruits and total seeds which are also given will be used for the determination of correlations in a subsequent section.

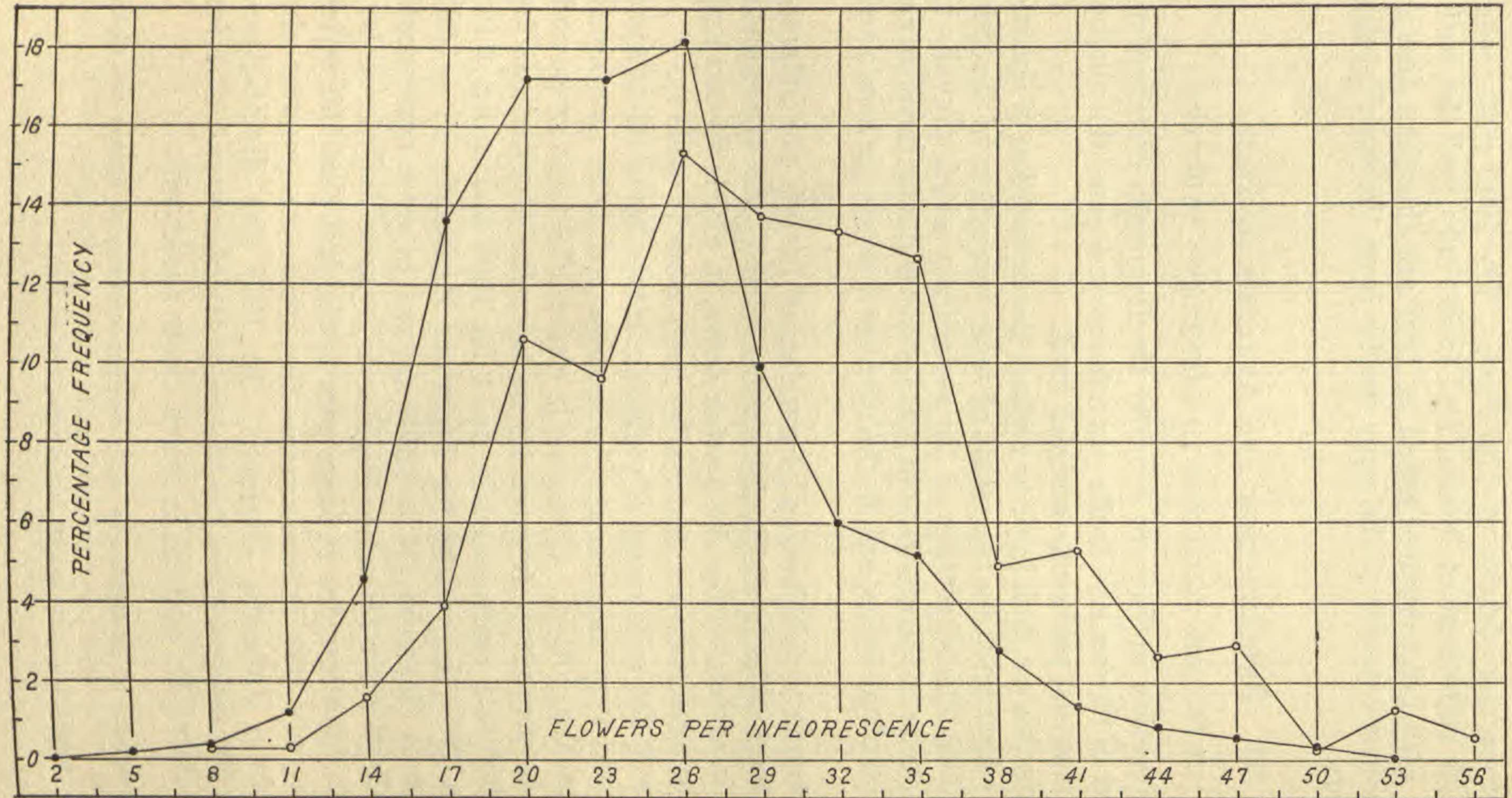


Fig. 1. Percentage frequency distribution of number of flowers per inflorescence in 2 habitats in 1906. Circles = Meramec Highlands, solid dots = Jefferson Barracks.


Fig. 2. Percentage frequency distribution of number of flowers per inflorescence in 2 habitats in 1907. Circles = Meramec Highlands, solid dots = Jefferson Barracks.

TABLE II

FREQUENCY DISTRIBUTION OF NUMBER OF FLOWERS PER INFLORESCENCE AND TOTAL NUMBER OF FRUITS ON EACH CLASS OF INFLORESCENCE IN 3 SERIES IN WHICH FLOWERS AND FRUITS ONLY WERE COUNTED

| Flowers | J. B. 1906 | | J. B. 1907 | | M. H. 1907 | |
|---|---|---|---|---|---|---|
| | f | Fruits | f | Fruits | f | Fruits |
| 4 | 1 | 2 | — | — | — | — |
| 6 | — | — | 1 | 2 | — | — |
| 7 | 2 | 4 | 2 | 5 | — | — |
| 8 | — | — | 1 | 2 | — | — |
| 9 | 1 | 1 | 4 | 11 | 1 | 2 |
| 10 | 1 | 2 | 2 | 2 | — | — |
| 11 | 5 | 13 | 4 | 12 | 2 | 6 |
| 12 | 3 | 8 | 9 | 26 | 2 | 4 |
| 13 | 11 | 31 | 18 | 50 | 2 | 6 |
| 14 | 14 | 39 | 19 | 70 | 5 | 15 |
| 15 | 17 | 49 | 15 | 51 | 6 | 15 |
| 16 | 42 | 140 | 30 | 116 | 8 | 34 |
| 17 | 43 | 160 | 22 | 87 | 5 | 20 |
| 18 | 49 | 190 | 26 | 108 | 15 | 56 |
| 19 | 53 | 209 | 39 | 167 | 7 | 33 |
| 20 | 51 | 208 | 39 | 170 | 10 | 47 |
| 21 | 54 | 239 | 37 | 162 | 12 | 48 |
| 22 | 59 | 262 | 66 | 340 | 16 | 78 |
| 23 | 54 | 258 | 52 | 246 | 5 | 28 |
| 24 | 64 | 327 | 43 | 227 | 17 | 86 |
| 25 | 58 | 312 | 46 | 276 | 14 | 72 |
| 26 | 58 | 364 | 30 | 172 | 18 | 105 |
| 27 | 78 | 415 | 40 | 248 | 7 | 39 |
| 28 | 36 | 226 | 46 | 285 | 13 | 72 |
| 29 | 36 | 260 | 43 | 296 | 10 | 51 |
| 30 | 33 | 219 | 31 | 212 | 10 | 69 |
| 31 | 24 | 180 | 36 | 302 | 14 | 94 |
| 32 | 23 | 156 | 30 | 218 | 10 | 66 |
| 33 | 17 | 111 | 41 | 290 | 11 | 71 |
| 34 | 19 | 146 | 25 | 204 | 16 | 106 |
| 35 | 16 | 117 | 23 | 184 | 6 | 46 |
| 36 | 15 | 111 | 27 | 236 | 5 | 42 |
| 37 | 9 | 69 | 23 | 190 | 7 | 48 |
| 38 | 10 | 99 | 16 | 146 | 10 | 75 |
| 39 | 9 | 87 | 22 | 196 | 5 | 42 |
| 40 | 6 | 48 | 11 | 99 | 7 | 69 |
| 41 | 5 | 48 | 13 | 131 | 6 | 52 |
| 42 | 4 | 36 | 15 | 137 | 2 | 22 |
| 43 | 3 | 31 | 10 | 115 | 4 | 35 |
| 44 | 2 | 9 | 11 | 113 | 2 | 22 |
| 45 | 3 | 32 | 12 | 131 | 4 | 21 |
| 46 | 5 | 54 | 9 | 92 | 1 | 18 |
| 47 | — | — | 4 | 50 | 2 | 21 |
| 48 | 2 | 23 | 7 | 100 | 3 | 44 |
| 49 | — | — | 3 | 43 | 3 | 36 |
| 50 | 2 | 23 | 3 | 31 | — | — |
| 51 | 2 | 32 | 3 | 34 | — | — |
| 52 | — | — | 4 | 46 | — | — |
| 53 | — | — | 2 | 22 | 1 | 20 |
| 54 | 1 | 11 | 1 | 14 | — | — |
| 56 | — | — | 1 | 12 | — | — |
| 57 | — | — | 1 | 19 | — | — |
| 58 | — | — | — | — | — | — |
| 59 | — | — | 1 | 9 | 1 | 13 |
| 66 | — | — | 1 | 27 | — | — |

TABLE III

STATISTICAL CONSTANTS FOR NUMBER OF FLOWERS PER INFLORESCENCE

| Series | N | Mean | Standard deviation | Coefficient of variation |
|---|---|---|---|---|
| Meramec Highlands 1906 (I) | 300 | 29.9467±.3304 | 8.4859±.2337 | 28.3367±0.8406 |
| Meramec Highlands 1907 (IV) | 300 | 27.6100±.3294 | 8.4592±.2330 | 30.6381±0.9195 |
| Meramec Highlands 1907 (V) | 305 | 28.2721±.3441 | 8.9098±.2433 | 31.5144±0.9422 |
| Meramec Highlands 1907 (IV)+(V) | 605 | 27.9438±.2384 | 8.6956±.1686 | 31.1181±0.6592 |
| Jefferson Barracks 1906 (II) | 250 | 23.4760±.3196 | 7.4929±.2260 | 31.9172±1.0561 |
| Jefferson Barracks 1906 (III) | 1000 | 24.7480±.1502 | 7.0461±.1062 | 28.4716±0.4628 |
| Jefferson Barracks 1906 (II)+(III) | 1250 | 24.4936±.1365 | 7.1558±.0965 | 29.2148±0.4260 |
| Jefferson Barracks 1907 (VI) | 250 | 27.2360±.3519 | 8.2479±.2488 | 30.2832±0.9935 |
| Jefferson Barracks 1907 (VII) | 1020 | 27.6078±.1943 | 9.2020±.1373 | 33.3312±0.5500 |
| Jefferson Barracks 1907 (VI)+(VII) | 1270 | 27.5346±.1708 | 9.0234±.1207 | 32.7711±0.4832 |

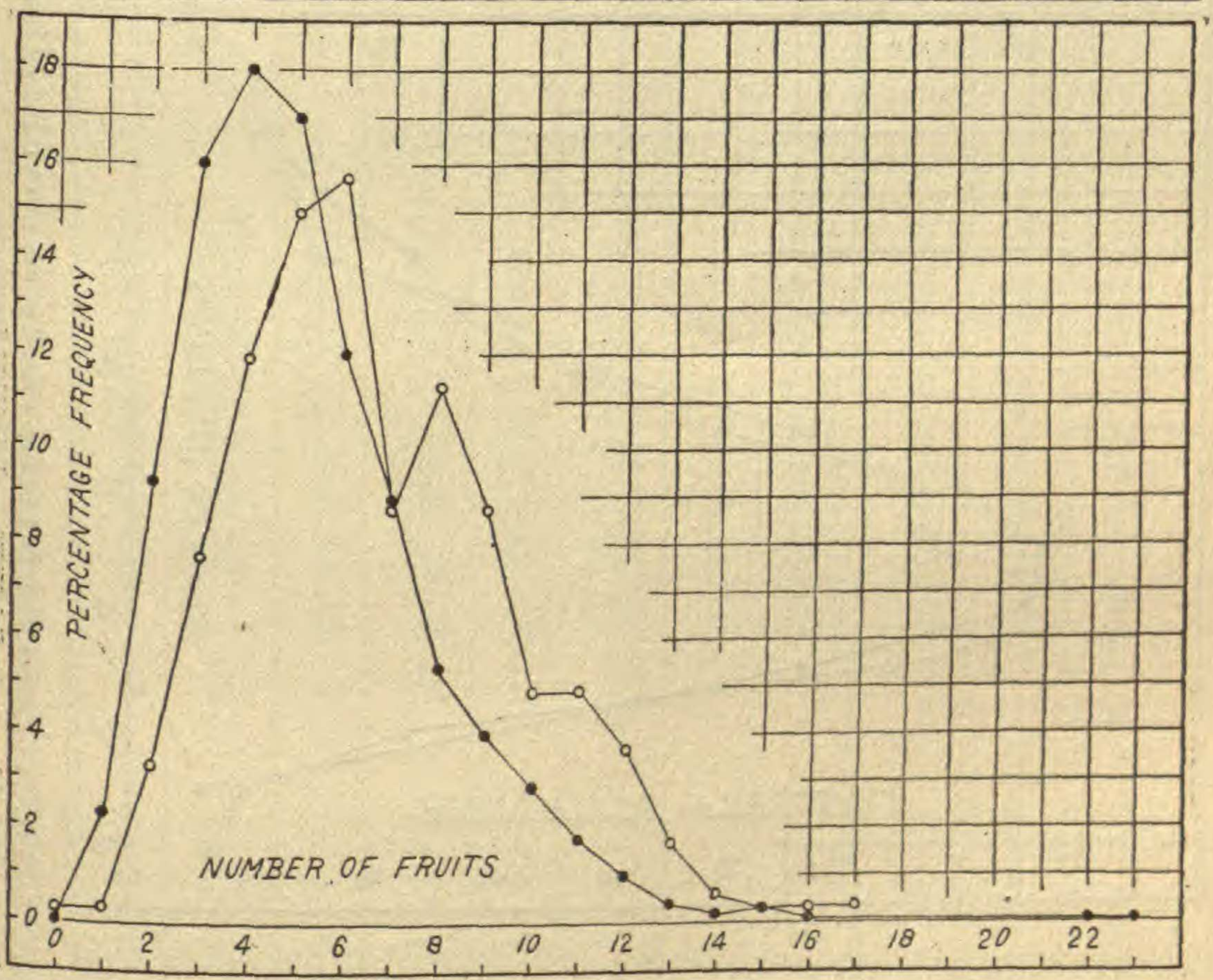


Fig. 3. Percentage frequency distribution of number of fruits per inflorescence in 2 habitats in 1906. Circles = Meramec Highlands, solid dots = Jefferson Barracks.

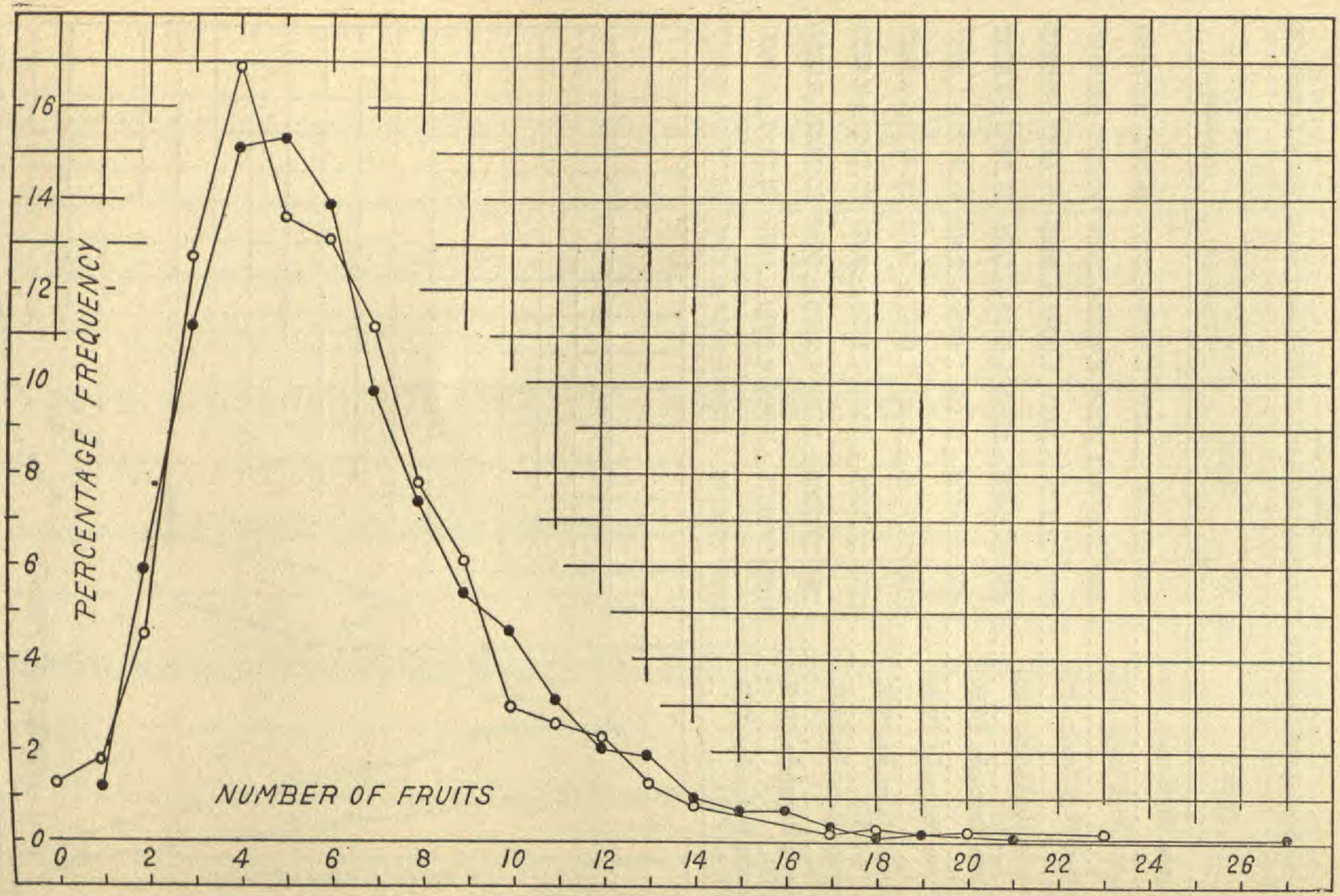


**Fig. 4.** Percentage frequency distribution of number of fruits per inflorescence in 2 habitats in 1907. Circles = Meramec Highlands, solid dots = Jefferson Barracks.

The fundamental variation constants, means, standard deviations and coefficients of variation of number of flowers per inflorescence in the several series of materials appear in table III. These will be discussed in comparison with those for number of fruits per inflorescence.

The frequency distribution of number of fruits per inflorescence in the 7 series of materials is shown in table IV. Series I, II + III, IV + V, and VI + VII have been reduced to percentage frequencies and are represented graphically in fig. 3 for 1906 and fig. 4 for 1907.

With the exception of the Meramec Highlands series for 1906, in which the number of observations is only 300, the frequencies

TABLE IV

FREQUENCY DISTRIBUTIONS OF NUMBER OF FRUITS PER INFLORESCENCE IN 7 SERIES AND TOTAL SEEDS PRODUCED ON EACH CLASS OF INFLORESCENCE IN 4 SERIES IN WHICH NUMBER OF SEEDS WAS DETERMINED

| Fruits | J. B. 1906 II | | J. B. 1907 VI | | M. H. 1906 I | | M. H. 1907 IV | | Series III | Series VII | Series V |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | f | Seeds | f | Seeds | f | Seeds | f | Seeds | f | f | f |
| 0 | — | — | — | — | — | — | — | — | — | — | 5 |
| 1 | 14 | 428 | 5 | 171 | 1 | 17 | 7 | 348 | 15 | 10 | 4 |
| 2 | 68 | 2427 | 28 | 957 | 20 | 985 | 24 | 991 | 82 | 61 | 15 |
| 3 | 165 | 5317 | 111 | 4367 | 69 | 3033 | 120 | 5138 | 145 | 105 | 37 |
| 4 | 184 | 5807 | 172 | 5682 | 144 | 5941 | 208 | 8521 | 179 | 149 | 50 |
| 5 | 155 | 4834 | 210 | 7198 | 225 | 9183 | 180 | 7399 | 183 | 152 | 46 |
| 6 | 126 | 4130 | 210 | 7128 | 282 | 12503 | 264 | 9620 | 129 | 141 | 35 |
| 7 | 105 | 2974 | 196 | 6184 | 183 | 7565 | 231 | 8067 | 96 | 96 | 35 |
| 8 | 96 | 3282 | 112 | 3255 | 272 | 10818 | 200 | 7229 | 55 | 80 | 22 |
| 9 | 54 | 1341 | 90 | 2525 | 234 | 9317 | 171 | 6727 | 44 | 59 | 18 |
| 10 | 80 | 2060 | 70 | 2497 | 150 | 6612 | 100 | 3616 | 28 | 51 | 8 |
| 11 | 33 | 991 | 66 | 2115 | 165 | 6658 | 44 | 1505 | 20 | 34 | 12 |
| 12 | 24 | 566 | 48 | 1329 | 132 | 4960 | 108 | 4239 | 10 | 22 | 5 |
| 13 | — | — | 26 | 685 | 65 | 2605 | 52 | 2028 | 5 | 22 | 4 |
| 14 | — | — | 14 | 579 | 28 | 1087 | 28 | 1126 | 2 | 11 | 3 |
| 15 | — | — | — | — | 15 | 621 | — | — | 4 | 9 | — |
| 16 | 16 | 454 | 16 | 328 | 16 | 641 | — | — | 1 | 8 | — |
| 17 | — | — | — | — | 16 | 781 | — | — | — | 4 | 1 |
| 18 | — | — | 18 | 398 | — | — | — | — | — | 1 | 2 |
| 19 | — | — | — | — | — | — | — | — | — | 3 | 1 |
| 20 | — | — | — | — | — | — | — | — | — | — | 1 |
| 21 | — | — | — | — | — | — | — | — | — | 1 | — |
| 22 | — | — | — | — | — | — | — | — | 1 | — | — |
| 23 | — | — | — | — | — | — | — | — | 1 | — | 1 |
| 24 | — | — | — | — | — | — | — | — | — | — | — |
| 25 | — | — | — | — | — | — | — | — | — | — | — |
| 26 | — | — | — | — | — | — | — | — | — | — | — |
| 27 | — | — | — | — | — | — | — | — | — | 1 | — |

form very smooth distributions. In all, a conspicuous skewness, a tendency to tail off in the direction of the larger number of fruits, is a characteristic feature.

The physical constants for number of fruits per inflorescence are shown for all the series in table V.

The first question concerning the statistical constants of both flowers and fruits which requires consideration is that of the difference between the means of the series for the different years in the same habitat and for the different habitats. The comparisons may be based upon the combination series in so far as these are

TABLE V

STATISTICAL CONSTANTS FOR NUMBER OF FRUITS PER INFLORESCENCE

| Series | N | Mean | Standard deviation | Coefficient of variation |
|---|---|---|---|---|
| Meramec Highlands 1906 (I) | 300 | 6.7233±.1134 | 2.9109±.0802 | 43.2958±1.3980 |
| Meramec Highlands 1907 (IV) | 300 | 5.7900±.1073 | 2.7554±.0759 | 47.5900±1.5798 |
| Meramec Highlands 1907 (V) | 305 | 6.0623±.1297 | 3.3593±.0917 | 55.4123±1.9226 |
| Meramec Highlands 1907 (IV)+(V) | 605 | 5.9273±.0843 | 3.0777±.0596 | 51.9247±1.2490 |
| Jefferson Barracks 1906 (II) | 250 | 4.4800±.1076 | 2.5222±.0761 | 56.2995±2.1704 |
| Jefferson Barracks 1906 (III) | 1000 | 5.3610±.1143 | 2.6162±.0808 | 48.8012±0.8941 |
| Jefferson Barracks 1906 (II)+(III) | 1250 | 5.1848±.0500 | 2.6215±.0353 | 50.5611±0.8378 |
| Jefferson Barracks 1907 (VI) | 250 | 5.5680±.1156 | 2.7095±.0817 | 48.6619±1.7815 |
| Jefferson Barracks 1907 (VII) | 1020 | 6.4059±.0701 | 3.3237±.0496 | 51.8852±0.9608 |
| Jefferson Barracks 1907 (VI)+(VII) | 1270 | 6.2409±.0611 | 3.2293±.0432 | 51.7442±0.8579 |

TABLE VI

COMPARISON OF THE STATISTICAL CONSTANTS FOR THE 2 DIFFERENT YEARS FOR PLANTS GROWING IN THE SAME HABITAT

| Difference 1906 less 1907 | Mean | Standard deviation | Coefficient of variation |
|---|---|---|---|
| Meramec Highlands | | | |
| Flowers | +2.0029±.4074 | −0.2097±.2882 | −2.7814±1.0682 |
| Fruits | +0.7960±.1413 | −0.1668±.0999 | −8.6289±1.8747 |
| Jefferson Barracks | | | |
| Flowers | −3.0410±.2186 | −1.8676±.1545 | −3.5563±0.6442 |
| Fruits | −1.0561±.0790 | −0.6078±.0558 | −1.1831±1.1991 |

available. Thus in comparing the results for the 2 years in the same habitat we may determine the differences between the means for series I and series IV + V for Meramec Highlands and for series II + III and series VI + VII for Jefferson Barracks. The differences for the two years are given in table VI, which shows that the average number of flowers and fruits is slightly, but significantly, higher at Meramec Highlands in 1906 than in 1907, whereas the reverse is true at Jefferson Barracks. The variabilities, both absolute (S. D.) and relative (C. V.) are higher for both flowers and fruits in both habitats in 1907 than in 1906.

We now have to consider the difference in the inflorescsence produced in the 2 habitats in the same year. The differences may be taken (Meramec Highlands) less (Jefferson Barracks).

The differences in table VII are obtained by comparing the results for series I (Meramec Highlands) and series II + III (Jefferson Barracks) for 1906, and for series IV + V (Meramec Highlands) and series VI + VII (Jefferson Barracks) for 1907. The differences in this table show that in both years the number

TABLE VII

COMPARISON OF THE STATISTICAL CONSTANTS FOR PLANTS GROWING IN THE DIFFERENT HABITATS IN THE SAME YEAR

| Difference | Mean | Standard deviation | Coefficient of variation |
|---|---|---|---|
| 1906 | | | |
| Flowers | +5.4531±.3575 | +1.3301±.2528 | −0.8781±0.9424 |
| Fruits | +1.5385±.1239 | +0.2894±.0876 | −7.2653±1.6298 |
| 1907 | | | |
| Flowers | +0.4092±.2933 | −0.3278±.2074 | −1.6530±0.8173 |
| Fruits | −0.3136±.1041 | −0.1516±.0736 | +0.1805±1.5153 |

of flowers is larger at Meramec Highlands than at Jefferson Barracks. The difference in 1907 is, however, insignificant. The number of fruits is slightly higher at Meramec Highlands in 1906 but slightly lower in 1907. The results of this comparison show that the differences between the 2 habitats are either nil or much smaller than would have been anticipated from a mere inspection of the 2 habitats.

We now turn to the question of relative values of the constants for number of flowers and number of fruits per inflorescence.

Comparing the mean number of flowers and fruits as given in tables III and V, we note that the average flower number ranges from 23.5 to 29.9, whereas the mean number of fruits range from 4.5 to 6.7. Thus only about 20 per cent of the flowers develop into fruits.

We also require some measure of the relative fruit production of the several series.

For this purpose we may make use of the coefficient of fecundity (Harris, '10), i. e., the ratio $\bar{c}/\bar{f}$.[1]

The coefficients are given in table VIII, which shows that about 22 per cent of the flowers develop into fruits. The probable errors are low, and the differences between the several series are

TABLE VIII

COEFFICIENTS OF FECUNDITY IN THE 4 SERIES

| Series | Number of inflorescences | Coefficient of fecundity |
|---|---|---|
| Meramec Highlands 1906 | 300 | .2245±.0030 |
| Meramec Highlands 1907 | 605 | .2121±.0021 |
| Jefferson Barracks 1906 | 1250 | .2117±.0016 |
| Jefferson Barracks 1907 | 1270 | .2267±.0015 |

possibly significant in comparison with their probable errors. The actual magnitude of the differences is, however, very small, being .0124 ± .004 for the 2 Meramec Highlands series, .0150 ± .002 for the 2 Jefferson Barracks series, .0128 ± .003 for the series from the 2 habitats in 1906, and .0146 ± .003 for the series from the 2 habitats in 1907.

The standard deviations as given in tables III and V for number of flowers range from 7.0 to 9.2, whereas those for number of fruits vary from 2.5 to 3.4 in the several series. The significance of the differences between the several lots of material has been discussed above. The absolute variability (standard deviation) of number of fruits per inflorescence is much smaller than that for number of flowers per inflorescence. In general the fruits are about one-third the comparable values for the flowers.

[1] The probable error of C. F., the coefficient of fecundity, is given by

$$.67449 \sqrt{c \times (1 - c/f)/f}.$$

The great difference in the mean number of flowers and fruits renders a discussion of the comparison of variability impossible except on the basis of constants involving correction for mean numbers. These constants are afforded by the coefficients of variation which show that the variation for number of fruits per inflorescence is regularly higher than that for number of flowers per inflorescence. The coefficients of variation for number of flowers range from 28.3 to 33.3, whereas those for number of fruits range from 43.3 to 56.3.

This result for relative variability in flower and fruit number is substantiated by results for *Crinum longifolium* and *Celastrus scandens*, but not for *Staphylea trifolia*. The actual coefficients are as follows:

| | Flowers | Fruits |
|---|---|---|
| *Crinum longifolium* (Harris, 1912 a) | 22.80–24.32 | 31.73–33.70 |
| *Celastrus scandens* (Harris, 1909) | 26.80 | 48.58 |
| *Staphylea trifolia* (Harris, 1909 a) | 64.44 | 53.04 |

In a series of inflorescences of varying numbers of flowers per inflorescence the distribution of the position of the flowers on the inflorescence must be considered in relation to the number of flowers in each position, the ovaries of which might have developed into capsules.

Table IX shows the number of flowers formed and the number of capsules matured in the various positions on the inflorescence for 3 of the series of data.[1] From these data the percentage frequencies of numbers of capsules matured in each position on the inflorescence have been derived and are represented in fig. 5. The higher positions, of course, occur only on the larger inflorescences. In any sample which it is practicable to secure, the numbers of flowers and fruits in the more distal positions are so small that percentages calculated upon them are very irregular. Only percentages based upon at least 100 flowers have been included in the diagram.

[1] The reader who cares to do so may determine the number of flowers and number of fruits for the 3 series of inflorescences in which number of flowers and number of fruits only was determined by subtracting the appropriate sections of table X from table IX.


Fig. 5 Percentage frequencies of flowers which develop into fruits in various positions on the inflorescence. Circles and solid lines = Meramec Highlands, 1907; solid dots and solid lines = Jefferson Barracks, 1906; solid dots and broken lines = Jefferson Barracks, 1907.

The 3 series of countings represented in the diagrams show essential agreement in that the relative number of capsules developing in the most proximal position is low. It increases rapidly to a maximum on about the sixth position. It then declines rapidly to about 17 per cent in the twentieth position, after which it remains about the same throughout the remainder of the inflorescence.[1]

TABLE IX

NUMBER OF FLOWERS AND FRUITS PRODUCED AT VARIOUS POSITIONS ON THE INFLORESCENCE IN 3 SERIES IN WHICH FLOWERS AND FRUITS ONLY WERE COUNTED

| P | J. B. 1906 | | J. B. 1907 | | M. H. 1907 | | P | J. B. 1906 | | J. B. 1907 | | M. H. 1907 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fl. | Fr. | Fl. | Fr. | Fl. | Fr. | | Fl. | Fr. | Fl. | Fr. | Fl. | Fr. |
| 1 | 1250 | 233 | 1270 | 251 | 605 | 100 | 34 | 143 | 22 | 308 | 53 | 155 | 23 |
| 2 | 1250 | 297 | 1270 | 287 | 605 | 108 | 35 | 119 | 12 | 274 | 40 | 126 | 22 |
| 3 | 1249 | 340 | 1270 | 351 | 605 | 102 | 36 | 99 | 18 | 239 | 31 | 110 | 21 |
| 4 | 1249 | 362 | 1270 | 356 | 605 | 152 | 37 | 78 | 12 | 207 | 40 | 99 | 13 |
| 5 | 1248 | 364 | 1270 | 379 | 605 | 141 | 38 | 67 | 15 | 178 | 26 | 86 | 15 |
| 6 | 1248 | 354 | 1270 | 422 | 605 | 169 | 39 | 53 | 12 | 160 | 23 | 72 | 13 |
| 7 | 1247 | 351 | 1269 | 409 | 605 | 193 | 40 | 43 | 6 | 134 | 21 | 62 | 12 |
| 8 | 1244 | 348 | 1267 | 395 | 604 | 172 | 41 | 36 | 5 | 120 | 16 | 50 | 10 |
| 9 | 1244 | 320 | 1266 | 378 | 603 | 159 | 42 | 30 | 8 | 104 | 22 | 40 | 10 |
| 10 | 1242 | 294 | 1262 | 339 | 601 | 148 | 43 | 25 | 6 | 86 | 18 | 35 | 7 |
| 11 | 1241 | 256 | 1259 | 361 | 601 | 139 | 44 | 20 | 5 | 74 | 12 | 28 | 9 |
| 12 | 1234 | 285 | 1255 | 321 | 598 | 130 | 45 | 18 | 1 | 60 | 12 | 21 | 5 |
| 13 | 1228 | 255 | 1246 | 297 | 596 | 128 | 46 | 14 | 3 | 44 | 4 | 18 | 5 |
| 14 | 1216 | 240 | 1226 | 288 | 590 | 134 | 47 | 9 | — | 33 | 5 | 15 | 2 |
| 15 | 1195 | 229 | 1202 | 259 | 585 | 140 | 48 | 8 | 1 | 28 | 5 | 13 | 3 |
| 16 | 1170 | 198 | 1185 | 223 | 573 | 116 | 49 | 6 | — | 21 | 2 | 10 | 2 |
| 17 | 1119 | 197 | 1149 | 210 | 558 | 122 | 50 | 6 | — | 18 | 2 | 7 | — |
| 18 | 1061 | 167 | 1116 | 189 | 547 | 106 | 51 | 3 | — | 15 | 2 | 7 | 1 |
| 19 | 1000 | 159 | 1078 | 177 | 522 | 91 | 52 | 1 | — | 12 | 1 | 5 | 3 |
| 20 | 930 | 134 | 1033 | 190 | 499 | 96 | 53 | 1 | — | 8 | — | 5 | — |
| 21 | 864 | 116 | 985 | 176 | 477 | 92 | 54 | 1 | — | 6 | 1 | 3 | — |
| 22 | 785 | 124 | 939 | 173 | 454 | 80 | 55 | — | — | 5 | — | 3 | — |
| 23 | 708 | 116 | 861 | 162 | 419 | 71 | 56 | — | — | 5 | — | 3 | — |
| 24 | 642 | 115 | 790 | 146 | 410 | 73 | 57 | — | — | 4 | — | 3 | 1 |
| 25 | 570 | 94 | 732 | 128 | 380 | 68 | 58 | — | — | 3 | — | 3 | 1 |
| 26 | 498 | 82 | 672 | 112 | 351 | 65 | 59 | — | — | 3 | — | 3 | 2 |
| 27 | 431 | 78 | 631 | 114 | 317 | 56 | 60 | — | — | 2 | — | 2 | — |
| 28 | 342 | 60 | 577 | 99 | 294 | 58 | 61 | — | — | 1 | — | — | — |
| 29 | 300 | 50 | 524 | 102 | 267 | 60 | 62 | — | — | 1 | — | — | — |
| 30 | 257 | 58 | 476 | 78 | 244 | 48 | 63 | — | — | 1 | 1 | — | — |
| 31 | 218 | 33 | 438 | 85 | 225 | 34 | 64 | — | — | 1 | 1 | — | — |
| 32 | 193 | 33 | 396 | 71 | 197 | 36 | 65 | — | — | 1 | 1 | — | — |
| 33 | 164 | 23 | 358 | 58 | 173 | 19 | 66 | — | — | 1 | 1 | — | — |

[1] There may be a secondary node at about the 29th to the 30th position. Possibly this is due to the fact that such positions are found only on the larger inflorescences.

## TABLE X

NUMBERS OF FLOWERS, FRUITS AND SEEDS AT VARIOUS POSITIONS ON THE INFLORESCENCE IN 4 SERIES IN WHICH NUMBER OF SEEDS WAS DETERMINED

| P | J. B. 1906 | | | J. B. 1907 | | | M. H. 1906 | | | M. H. 1907 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fl. | Fr. | S. | Fl. | Fr. | S. | Fl. | Fr. | S. | Fl. | Fr. | S. |
| 1 | 250 | 31 | 1062 | 250 | 39 | 1416 | 300 | 60 | 2585 | 300 | 58 | 2187 |
| 2 | 250 | 40 | 1269 | 250 | 49 | 1777 | 300 | 75 | 3032 | 300 | 56 | 2151 |
| 3 | 249 | 44 | 1715 | 250 | 58 | 2023 | 300 | 87 | 3660 | 300 | 55 | 2087 |
| 4 | 249 | 57 | 2130 | 250 | 70 | 2537 | 300 | 93 | 4044 | 300 | 77 | 3035 |
| 5 | 249 | 48 | 1605 | 250 | 71 | 2391 | 300 | 86 | 3483 | 300 | 75 | 2969 |
| 6 | 249 | 49 | 1801 | 250 | 73 | 2487 | 300 | 97 | 4251 | 300 | 90 | 3794 |
| 7 | 248 | 48 | 1376 | 250 | 68 | 2466 | 300 | 82 | 3569 | 300 | 94 | 3722 |
| 8 | 247 | 52 | 1687 | 250 | 85 | 2708 | 300 | 72 | 2876 | 299 | 82 | 3468 |
| 9 | 247 | 52 | 1639 | 250 | 85 | 3051 | 300 | 77 | 3444 | 298 | 79 | 3187 |
| 10 | 246 | 43 | 1501 | 250 | 63 | 2049 | 299 | 75 | 2991 | 297 | 72 | 2932 |
| 11 | 246 | 37 | 1121 | 249 | 70 | 2173 | 299 | 76 | 3263 | 297 | 68 | 3041 |
| 12 | 244 | 53 | 1717 | 249 | 60 | 1795 | 299 | 62 | 2733 | 296 | 72 | 2595 |
| 13 | 241 | 53 | 1460 | 249 | 45 | 1532 | 298 | 65 | 2566 | 296 | 59 | 2301 |
| 14 | 240 | 53 | 1332 | 247 | 49 | 1564 | 296 | 66 | 2886 | 292 | 61 | 2411 |
| 15 | 233 | 40 | 1121 | 242 | 42 | 1345 | 294 | 67 | 2937 | 292 | 66 | 2804 |
| 16 | 225 | 40 | 1254 | 240 | 47 | 1626 | 293 | 71 | 3064 | 286 | 56 | 2192 |
| 17 | 216 | 52 | 1182 | 234 | 30 | 1003 | 291 | 65 | 2532 | 279 | 56 | 2251 |
| 18 | 201 | 45 | 1389 | 223 | 34 | 1117 | 287 | 55 | 2590 | 273 | 55 | 1911 |
| 19 | 189 | 40 | 1172 | 211 | 37 | 1222 | 281 | 62 | 2691 | 263 | 49 | 1697 |
| 20 | 172 | 30 | 808 | 205 | 35 | 1099 | 273 | 60 | 2488 | 247 | 43 | 1558 |
| 21 | 157 | 22 | 779 | 194 | 28 | 727 | 263 | 40 | 1569 | 235 | 39 | 1363 |
| 22 | 132 | 29 | 925 | 188 | 26 | 728 | 249 | 49 | 1904 | 224 | 34 | 1180 |
| 23 | 114 | 22 | 576 | 174 | 24 | 848 | 239 | 50 | 2068 | 205 | 35 | 1276 |
| 24 | 102 | 23 | 841 | 156 | 22 | 528 | 232 | 45 | 1643 | 201 | 33 | 1037 |
| 25 | 94 | 19 | 573 | 142 | 17 | 482 | 220 | 38 | 1495 | 188 | 35 | 1482 |
| 26 | 80 | 17 | 477 | 127 | 18 | 508 | 207 | 55 | 2024 | 173 | 32 | 1093 |
| 27 | 71 | 13 | 327 | 116 | 14 | 414 | 192 | 32 | 1324 | 157 | 30 | 1136 |
| 28 | 60 | 7 | 259 | 102 | 14 | 384 | 174 | 30 | 1156 | 141 | 26 | 992 |
| 29 | 54 | 10 | 224 | 95 | 15 | 489 | 157 | 25 | 1018 | 127 | 24 | 739 |
| 30 | 47 | 5 | 114 | 90 | 11 | 332 | 146 | 24 | 920 | 114 | 21 | 760 |
| 31 | 41 | 6 | 234 | 83 | 17 | 542 | 133 | 34 | 1288 | 105 | 14 | 418 |
| 32 | 40 | 8 | 175 | 77 | 13 | 415 | 115 | 14 | 686 | 91 | 10 | 324 |
| 33 | 34 | 6 | 165 | 69 | 13 | 410 | 109 | 23 | 753 | 77 | 9 | 261 |
| 34 | 30 | 5 | 131 | 60 | 8 | 257 | 93 | 17 | 585 | 70 | 8 | 273 |
| 35 | 25 | 2 | 56 | 51 | 4 | 59 | 81 | 11 | 372 | 57 | 12 | 310 |
| 36 | 21 | 3 | 68 | 39 | 8 | 215 | 64 | 9 | 401 | 47 | 6 | 170 |
| 37 | 15 | 1 | 5 | 34 | 3 | 52 | 55 | 11 | 430 | 44 | 9 | 298 |
| 38 | 13 | 3 | 121 | 28 | 3 | 86 | 48 | 9 | 315 | 35 | 4 | 169 |
| 39 | 9 | 1 | 30 | 26 | 4 | 72 | 45 | 8 | 287 | 31 | 5 | 183 |
| 40 | 8 | 2 | 63 | 22 | 3 | 44 | 40 | 6 | 203 | 26 | 6 | 159 |
| 41 | 7 | 2 | 50 | 19 | 3 | 51 | 34 | 6 | 236 | 21 | 3 | 45 |
| 42 | 6 | 2 | 15 | 16 | 5 | 95 | 31 | 6 | 232 | 17 | 2 | 64 |
| 43 | 5 | 2 | 29 | 13 | 2 | 92 | 24 | 6 | 204 | 14 | 4 | 151 |
| 44 | 3 | 2 | 5 | 11 | 3 | 89 | 23 | 5 | 151 | 11 | 3 | 76 |
| 45 | 3 | — | — | 8 | 2 | 80 | 21 | 1 | 22 | 7 | 2 | 120 |
| 46 | 2 | 1 | 28 | 5 | 1 | 16 | 16 | — | — | 6 | 2 | 60 |
| 47 | 2 | — | — | 2 | 1 | 12 | 13 | 1 | 42 | 5 | — | 10 |
| 48 | 1 | — | — | 1 | — | — | 12 | 3 | 81 | 5 | 1 | 28 |
| 49 | 1 | — | — | 1 | — | — | 7 | 1 | 30 | 5 | 1 | 25 |
| 50 | 1 | — | — | 1 | — | — | 6 | — | — | 5 | — | 31 |
| 51 | — | — | — | 1 | — | — | 6 | 2 | 46 | 5 | — | 28 |
| 52 | — | — | — | 1 | — | — | 6 | 1 | 50 | 3 | 2 | — |
| 53 | — | — | — | 1 | — | — | 6 | 1 | 64 | 3 | — | — |
| 54 | — | — | — | 1 | — | — | 5 | 1 | 43 | 2 | — | — |
| 55 | — | — | — | 1 | — | — | 2 | — | — | 2 | — | — |
| 56 | — | — | — | 1 | — | — | — | — | — | 2 | — | — |
| 57 | — | — | — | 1 | — | — | — | — | — | 2 | — | — |
| 58 | — | — | — | 1 | — | — | — | — | — | 2 | 1 | — |
| 59 | — | — | — | 1 | — | — | — | — | — | 2 | 1 | — |
| 60 | — | — | — | 1 | — | — | — | — | — | 2 | — | — |

The investigation of this question has its obvious bearing on the problem of periodicity. Periodicity is the term used by de Vries and other biologists to express the idea that the form or size of the organs produced laterally along an axis is to some extent correlated with their position in such a manner that as one passes from the proximal to the distal region of the axis there is at first an increase to a maximum and then a decrease of the value of the character of the laterally produced organ.

TABLE XI

FREQUENCY DISTRIBUTION OF NUMBER OF SEEDS PER LOCULE IN 4 SERIES

| Seeds per locule | J. B. 1906 | J. B. 1907 | M. H. 1906 | M. H. 1907 |
|---|---|---|---|---|
| ? | — | 14 | — | 10 |
| 0 | 307 | 212 | 104 | 129 |
| 1 | 117 | 96 | 51 | 80 |
| 2 | 139 | 138 | 91 | 86 |
| 3 | 172 | 162 | 145 | 130 |
| 4 | 153 | 173 | 153 | 157 |
| 5 | 153 | 161 | 189 | 200 |
| 6 | 164 | 206 | 224 | 207 |
| 7 | 143 | 225 | 245 | 249 |
| 8 | 143 | 215 | 278 | 224 |
| 9 | 173 | 218 | 287 | 253 |
| 10 | 143 | 214 | 293 | 264 |
| 11 | 161 | 213 | 280 | 280 |
| 12 | 124 | 243 | 329 | 315 |
| 13 | 133 | 219 | 291 | 302 |
| 14 | 151 | 214 | 300 | 278 |
| 15 | 128 | 218 | 311 | 255 |
| 16 | 134 | 159 | 348 | 278 |
| 17 | 110 | 183 | 292 | 242 |
| 18 | 105 | 175 | 286 | 219 |
| 19 | 93 | 111 | 291 | 197 |
| 20 | 82 | 96 | 218 | 194 |
| 21 | 77 | 85 | 199 | 106 |
| 22 | 66 | 77 | 198 | 130 |
| 23 | 40 | 42 | 169 | 109 |
| 24 | 40 | 27 | 136 | 82 |
| 25 | 35 | 34 | 84 | 60 |
| 26 | 28 | 13 | 79 | 54 |
| 27 | 15 | 16 | 59 | 36 |
| 28 | 10 | 9 | 32 | 37 |
| 29 | 8 | 5 | 27 | 14 |
| 30 | 6 | 1 | 28 | 12 |
| 31 | 4 | — | 12 | 8 |
| 32 | — | 2 | 11 | 5 |
| 33 | 1 | — | 2 | 4 |
| 34 | 2 | — | 3 | 1 |
| 35 | — | — | 3 | — |
| 36 | — | — | 1 | 2 |
| 37 | — | — | — | 1 |
| 38 | — | — | 2 | 1 |

The literature bearing on this problem is now fairly extensive, but little has been written concerning the possible relationship between the fertility characters of the fruit and its position on the inflorescence axis.

It should be evident that the differences in the proportion of fruits developing at different positions on the inflorescence present a series of problems of morphogenetic and physiological significance. Unfortunately the systematic collection of data for the solution of such problems has hardly been begun.

TABLE XII

FREQUENCY DISTRIBUTION OF NUMBER OF SEEDS PER FRUIT IN 4 SERIES

| Seeds per capsule | II | VI | I | IV | Seeds | II | VI | I | IV | Seeds | II | VI | I | IV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ? | — | 13 | — | 8 | 36 | 22 | 24 | 31 | 32 | 73 | 3 | 4 | 6 | 8 |
| 0 | 47 | 44 | 1 | 17 | 37 | 18 | 29 | 28 | 30 | 74 | 3 | 1 | 8 | 8 |
| 1 | 8 | 3 | — | 3 | 38 | 18 | 34 | 38 | 34 | 75 | 5 | — | 9 | 5 |
| 2 | 16 | 1 | — | 1 | 39 | 20 | 34 | 41 | 40 | 76 | 1 | 2 | 5 | 6 |
| 3 | 15 | 5 | 2 | 1 | 40 | 16 | 18 | 40 | 35 | 77 | 1 | 2 | 4 | 2 |
| 4 | 16 | 9 | 2 | 3 | 41 | 19 | 24 | 35 | 41 | 78 | 2 | 3 | 12 | 3 |
| 5 | 16 | 11 | 2 | 11 | 42 | 18 | 19 | 34 | 26 | 79 | 1 | 1 | 9 | 6 |
| 6 | 13 | 9 | 7 | 8 | 43 | 9 | 23 | 39 | 31 | 80 | 3 | — | 8 | 5 |
| 7 | 16 | 12 | 8 | 7 | 44 | 16 | 21 | 37 | 33 | 81 | 2 | 2 | 8 | 1 |
| 8 | 16 | 16 | 13 | 15 | 45 | 13 | 29 | 36 | 33 | 82 | — | — | 2 | 1 |
| 9 | 20 | 19 | 15 | 11 | 46 | 17 | 19 | 44 | 38 | 83 | 1 | — | 4 | 3 |
| 10 | 15 | 20 | 16 | 15 | 47 | 11 | 31 | 36 | 39 | 84 | 1 | — | 1 | 3 |
| 11 | 15 | 16 | 10 | 18 | 48 | 16 | 30 | 31 | 27 | 85 | 3 | 1 | 3 | 4 |
| 12 | 20 | 24 | 14 | 15 | 49 | 16 | 26 | 38 | 33 | 86 | 1 | — | 2 | 2 |
| 13 | 19 | 22 | 25 | 21 | 50 | 14 | 23 | 38 | 23 | 87 | — | — | 3 | — |
| 14 | 20 | 13 | 16 | 12 | 51 | 17 | 22 | 36 | 24 | 88 | — | — | — | 2 |
| 15 | 21 | 28 | 20 | 15 | 52 | 12 | 15 | 36 | 22 | 89 | — | — | — | — |
| 16 | 28 | 12 | 31 | 22 | 53 | 8 | 15 | 29 | 23 | 90 | — | — | 1 | — |
| 17 | 28 | 21 | 17 | 25 | 54 | 13 | 12 | 31 | 26 | 91 | — | — | 1 | — |
| 18 | 14 | 30 | 23 | 17 | 55 | 17 | 10 | 34 | 22 | 92 | — | 1 | 1 | 1 |
| 19 | 27 | 29 | 25 | 31 | 56 | 12 | 14 | 36 | 21 | 93 | — | — | 3 | — |
| 20 | 26 | 32 | 31 | 30 | 57 | 8 | 13 | 42 | 20 | 94 | — | — | 1 | 1 |
| 21 | 19 | 16 | 34 | 33 | 58 | 10 | 12 | 30 | 24 | 95 | — | — | — | — |
| 22 | 15 | 29 | 50 | 35 | 59 | 6 | 7 | 34 | 12 | 96 | — | — | 1 | — |
| 23 | 13 | 24 | 29 | 34 | 60 | 13 | 5 | 19 | 15 | 97 | 1 | — | — | 1 |
| 24 | 16 | 26 | 31 | 26 | 61 | 13 | 10 | 28 | 21 | 98 | — | — | — | — |
| 25 | 24 | 22 | 24 | 31 | 62 | 6 | 13 | 25 | 17 | 99 | — | — | 2 | — |
| 26 | 18 | 34 | 33 | 26 | 63 | 7 | 10 | 30 | 22 | 100 | — | — | — | — |
| 27 | 13 | 32 | 45 | 37 | 64 | 3 | 8 | 24 | 14 | 101 | — | — | — | — |
| 28 | 31 | 31 | 29 | 34 | 65 | 5 | 8 | 16 | 15 | 102 | — | — | 1 | — |
| 29 | 17 | 29 | 43 | 38 | 66 | 5 | 9 | 21 | 8 | 103 | — | — | — | — |
| 30 | 17 | 23 | 38 | 28 | 67 | 5 | 5 | 21 | 17 | 104 | — | — | — | — |
| 31 | 15 | 33 | 45 | 35 | 68 | 6 | 5 | 12 | 12 | 105 | — | — | — | — |
| 32 | 11 | 19 | 30 | 28 | 69 | 2 | 5 | 11 | 11 | 106 | — | — | — | — |
| 33 | 14 | 22 | 40 | 40 | 70 | 6 | 2 | 13 | 11 | 107 | — | — | — | 1 |
| 34 | 12 | 28 | 37 | 34 | 71 | 4 | 2 | 15 | 9 | 108 | — | — | — | — |
| 35 | 14 | 31 | 37 | 43 | 72 | 6 | 1 | 10 | 5 | 109 | — | — | — | — |

Looking at the matter in a wholly superficial way, one is inclined to suggest, as a basis for the planning of further investigation, that the maturation of the more proximal ovaries is not favored by the conditions of the inflorescence which are most favorable for the development of the terminal portions where the floral parts are being matured for anthesis. The failure of the more distally placed ovaries to develop to maturity in such large numbers as those in the more central region of the inflorescence is possibly attributable to the demands for fruit- and seed-forming substances made by more proximal ovaries already in an advanced stage of development.

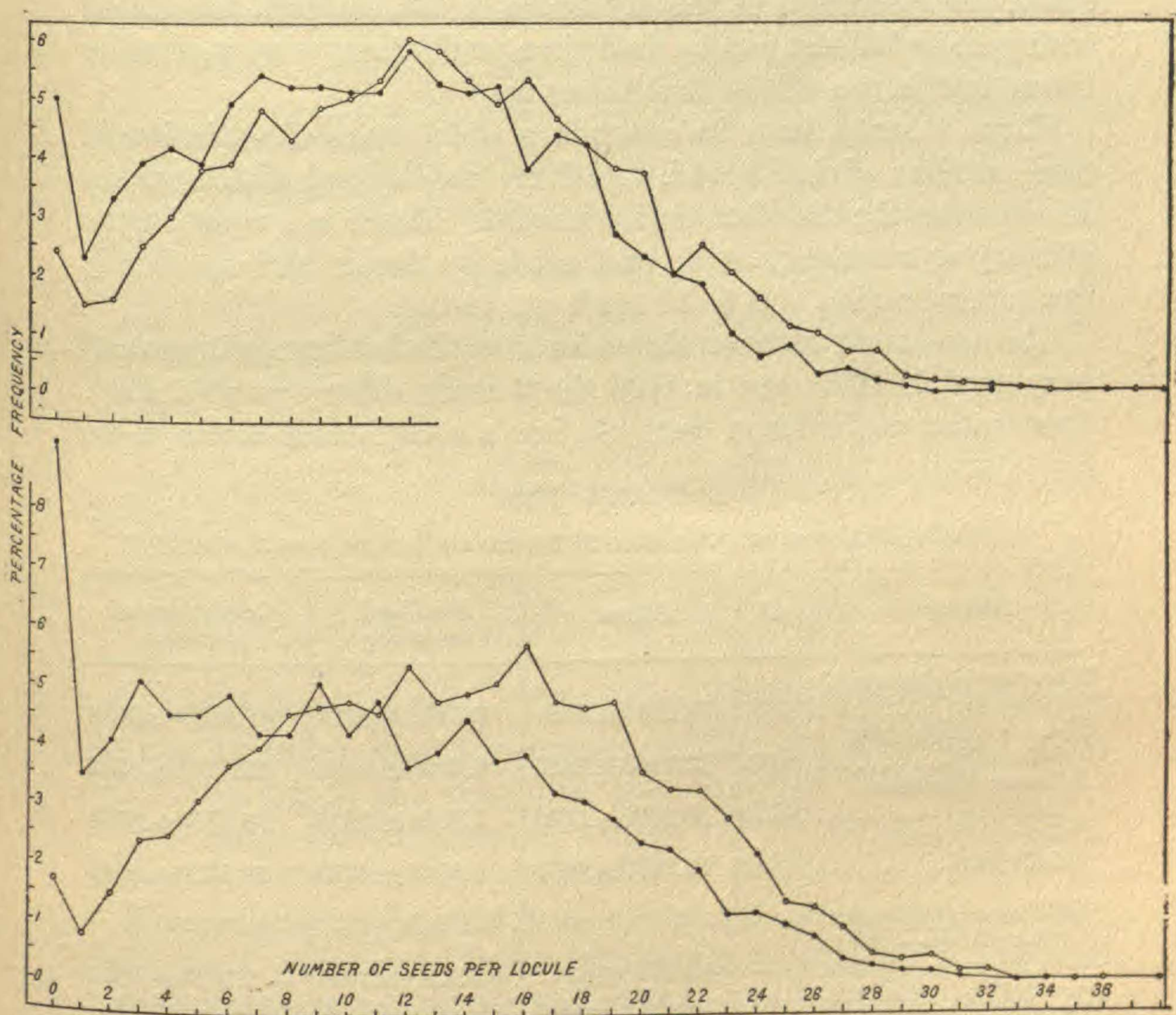


Fig. 6. Percentage frequency distribution of number of seeds per locule. Circles = Meramec Highlands, solid dots = Jefferson Barracks. Lower figure represents results for 1906, upper figure those for 1907.

The frequency distribution of number of seeds per locule in the 4 series is shown in table XI, while the distribution of number of seeds per capsule, comprising 3 locules, appears in table XII.

The distributions of seeds per locule, reduced to percentage frequencies, are represented graphically in fig. 6. These distributions require consideration from 2 sides: first, that of the differences between the series collected in different years in the same habitat, or in different habitats in the same year; second, that of their general nature as considered in comparison with biological frequency distribution in general. While neither of these questions can be fully considered independently of the other, the discussion of the difference in the material associated with year or habitat can be made in a preliminary way in simpler terms, and hence will be first taken up.

These 4 series have in common a wide range of variation in seed number, giving broad, relatively flat-topped distributions. In all series the distribution is bimodal. There is a conspicuous primary or secondary mode on 0 seeds per locule and another in the general region of 8 to 14 seeds per locule.

The agreement between the series from the habitats is in general very good in 1907, but in 1906 the 2 series differ conspicuously. That taken at Jefferson Barracks has a conspicuous mode on no

TABLE XIII

STATISTICAL CONSTANTS FOR NUMBER OF SEEDS PER LOCULE

| Series | N | Mean | Standard deviation | Coefficient of variation |
|---|---|---|---|---|
| Meramec Highlands 1906 (I) | 6051 | 13.7708±.0588 | 6.7898±.0416 | 49.3058±.3684 |
| Meramec Highlands 1907 (IV) | 5201 | 12.7963±.0623 | 6.6698±.0440 | 52.1229±.4280 |
| Jefferson Barracks 1906 (II) | 3360 | 10.3009±.0842 | 7.2394±.0595 | 70.2793±.8154 |
| Jefferson Barracks 1907 (VI) | 4162 | 10.9077±.0670 | 6.4086±.0473 | 58.7530±.5645 |
| Differences between two years (1906—1907) | | | | |
| Meramec Highlands | — | +0.9745±.0857 | +0.1200±.0607 | — 2.8171±.5647 |
| Jefferson Barracks | — | −0.6068±.1076 | +0.8308±.0760 | +11.5263±.9917 |
| Differences between two habitats (M.H.—J.B.) | | | | |
| 1906 | — | +3.4699±.1027 | −0.4496±.0726 | −20.9735±.8948 |
| 1907 | — | +1.8886±.0915 | +0.2612±.0646 | — 6.6301±.7084 |

seeds matured, and relatively high frequencies on the lower numbers of seeds per locule, whereas that taken at Meramec Highlands shows a relatively low mode on 0 seeds matured with a shift of the mode to a much higher seed number than in the Jefferson Barracks series.

To carry these comparisons somewhat further, and to prepare for more detailed consideration of the nature of these frequency distributions, we may consider the simpler statistical constants in table XIII for number of seeds per locule and in table XIV for

TABLE XIV

STATISTICAL CONSTANTS FOR NUMBER OF SEEDS PER FRUIT

| Series | N | Mean | Standard deviation | Coefficient of variation |
|---|---|---|---|---|
| Meramec Highlands 1906 (I) | 2017 | 41.3123±.2748 | 18.3094±.1944 | 44.3195± .5548 |
| Meramec Highlands 1907 (IV) | 1729 | 38.3829±.2947 | 18.1931±.2085 | 47.3991± .6539 |
| Jefferson Barracks 1906 (II) | 1120 | 30.9027±.4063 | 20.1417±.2872 | 65.1777±1.2631 |
| Jefferson Barracks 1907 (VI) | 1379 | 32.8426±.3165 | 17.4688±.2240 | 53.1893± .8545 |
| Differences between two years (1906—1907) | | | | |
| Meramec Highlands | — | + 2.9294±.4029 | +0.1163±.2851 | — 3.0796± .8575 |
| JeffersonBarracks | — | — 1.9399±.5150 | +2.6729±.3642 | +11.9884±1.5250 |
| Differences between two habitats (M. H.—J. B.) | | | | |
| 1906 | — | +10.4096±.4905 | —1.8323±.3468 | —20.8582±1.3796 |
| 1907 | — | + 5.5403±.4325 | +0.7243±.3060 | — 5.7902±1.0760 |

number of seeds per fruit. The differences between the constants for the 2 years in the same habitat and between the constants for the 2 habitats in the same year also appear in these tables.

The means and standard deviations will be used in calculating the coefficients of correlation set forth in the following paragraphs.

The conspicuous feature of the tables is the large size of the coefficients of variation. It is unnecessary in this place to bring together the many coefficients of variation for number of seeds per locule or per fruit which have been published in the literature, or to do more than to say that they are generally large.

Turning to the comparisons between the 2 years in the same habitat, we note that while the difference in means is perhaps statistically significant[1] in the 2 cases it is relatively small, being about 5 per cent in the 2 instances. It is also to be noted that in one habitat it is the 1906 series, whereas in the other it is the 1907 series, which has the higher seed production.

The differences between the 2 habitats in the same year show that for both years seed production is materially and significantly higher in the Meramec Highlands than in the Jefferson Barracks plants.

### 2. THE RELATIONSHIP BETWEEN THE NUMBER OF FLOWERS AND THE NUMBER OF CAPSULES MATURED

The relationship between number of flowers per inflorescence and the number of fruits per inflorescence may be computed for

TABLE XV

CORRELATION BETWEEN NUMBER OF FLOWERS AND FRUITS PER INFLORESCENCE

| Series | N | Correlation between number of flowers and fruits | $\frac{r}{E_r}$ | Correlation, flowers per inflorescence, and deviation of fruits from their probable value | $\frac{r}{E_r}$ |
|---|---|---|---|---|---|
| Meramec Highlands 1906 (I) | 300 | .6751±.0212 | 31.84 | .0278±.0389 | 0.71 |
| Meramec Highlands 1907 (IV) | 300 | .6565±.0222 | 29.57 | –.0986±.0386 | 2.55 |
| Meramec Highlands 1907 (V) | 305 | .6047±.0245 | 24.68 | .0451±.0385 | 1.17 |
| Meramec Highlands 1907 (IV)+(V) | 605 | .6261±.0167 | 37.49 | .0343±.0274 | 1.25 |
| Jefferson Barracks 1906 (II) | 250 | .6125±.0267 | 22.94 | .0576±.0425 | 1.36 |
| Jefferson Barracks 1906 (III) | 1000 | .6416±.0125 | 51.33 | .0693±.0212 | 3.27 |
| Jefferson Barracks 1906 (II)+(III) | 1250 | .6374±.0113 | 56.41 | .0771±.0190 | 4.06 |
| Jefferson Barracks 1907 (VI) | 250 | .5344±.0304 | 17.58 | –.1035±.0422 | 2.45 |
| Jefferson Barracks 1907 (VII) | 1020 | .6897±.0111 | 62.14 | .0652±.0210 | 3.10 |
| Jefferson Barracks 1907 (VI)+(VII) | 1270 | .6638±.0106 | 62.62 | .0407±.0189 | 2.15 |

the 4 series in which the seeds were counted from the entries in table I. For the 3 other series in which only the number of flowers and fruits were determined the reader must refer to table II.

The relationship between the number of flowers formed and the number of capsules matured per inflorescence is expressed in

[1] The ordinary formulae have been used in calculating the probable errors, although the correlation between the locules of the same fruit complicates somewhat their interpretation.

terms of correlations in the first correlation column of table XV. These coefficients are remarkably uniform from series to series. They range from $0.534 \pm 0.030$ to $0.690 \pm 0.011$. These *extremes* differ by only $0.156 \pm 0.032$. In general the series cannot be considered to differ significantly in correlation.

The relationship between the number of capsules matured and the number of flowers formed is expressed in terms of linear regression equations in table XVI.

TABLE XVI

STRAIGHT LINE EQUATIONS SHOWING THE RELATIONSHIP BETWEEN NUMBER OF FRUITS AND FLOWERS PER INFLORESCENCE

| Series | Regression equation |
|---|---|
| Meramec Highlands 1906 (I) | $c = -.2113 + .2316f$ |
| Meramec Highlands 1907 (IV) | $c = -.1139 + .2138f$ |
| Meramec Highlands 1907 (V) | $c = -.3830 + .2280f$ |
| Meramec Highlands 1907 (IV) + (V) | $c = -.2652 + .2216f$ |
| Jefferson Barracks 1906 (II) | $c = -.3602 + .2062f$ |
| Jefferson Barracks 1906 (III) | $c = -.5348 + .2382f$ |
| Jefferson Barracks 1906 (II) + (III) | $c = -.5346 + .2335f$ |
| Jefferson Barracks 1907 (VI) | $c = +.7869 + .1755f$ |
| Jefferson Barracks 1907 (VII) | $c = -.4719 + .2491f$ |
| Jefferson Barracks 1907 (VI) + (VII) | $c = -.3002 + .2376f$ |

The slopes of these lines range from + .1755 in the series of 250 inflorescences taken at Jefferson Barracks in 1907 to + .2491 in the large series taken at the same locality in the same year.

The fact that the widest disagreement is found in 2 series from the same habitat and year emphasizes the closeness of agreement between the results of the several series.

The equations for 2 of the series are represented graphically in fig. 7 for 1906, in which the empirical and theoretical means for 2 different habitats but for the same year, are laid side by side.

Two features of these diagrams will at once attract the eye: first, the excellent fit of the straight lines to the data; second, the remarkable closeness of agreement of the series from the 2 habitats.

While the correlation coefficients and the regression equations showing the relationship between the number of flowers and capsules per inflorescence have descriptive value, the physiological interrelationship between $f$ and $c$ may be best shown by a coefficient measuring the relationship between the number of flowers

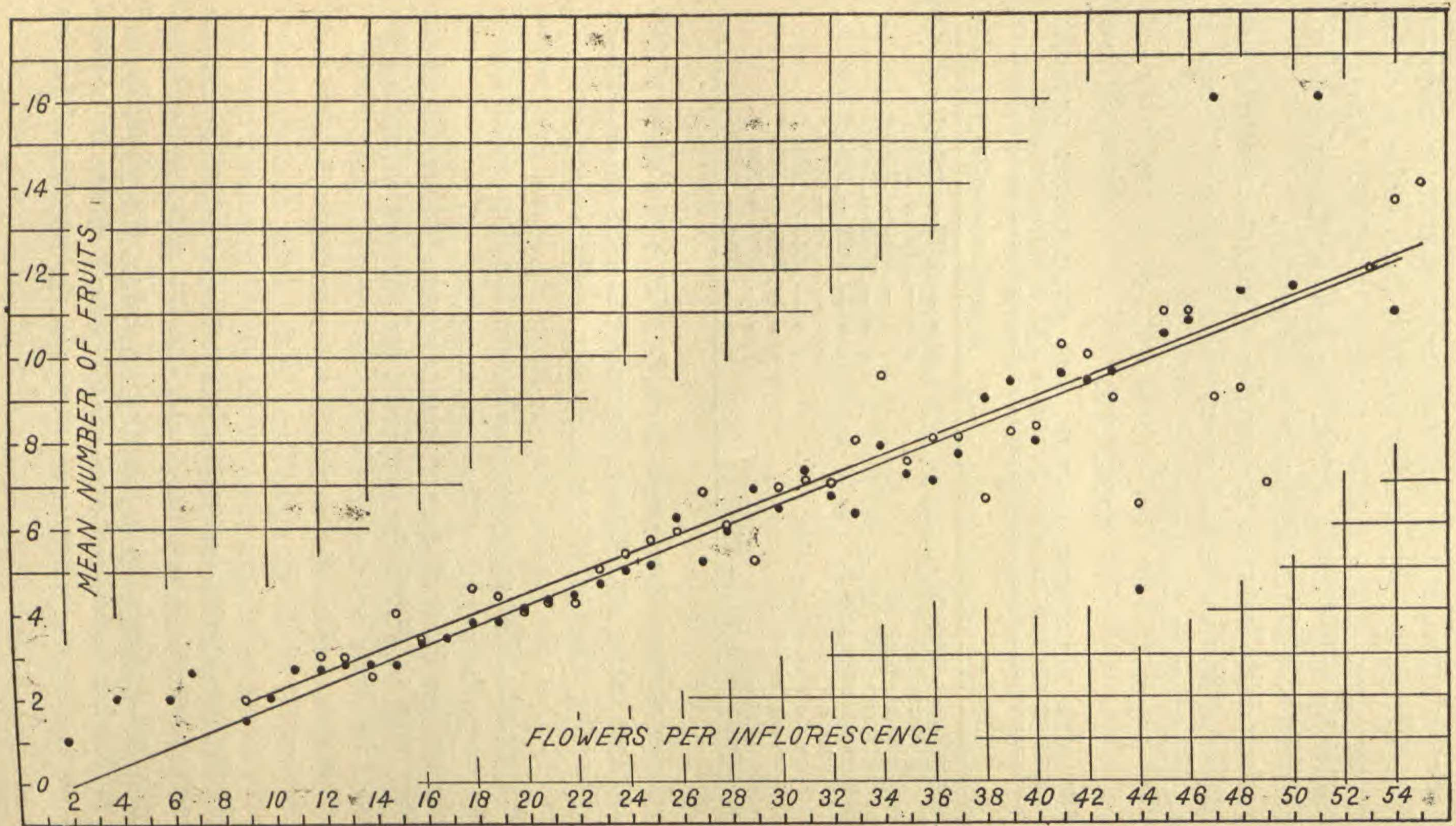


Fig. 7. Regression of number of fruits on number of flowers per inflorescence. Upper line = Meramec Highlands; lower line = Jefferson Barracks. Empirical means for Meramec Highlands represented by circles, those for Jefferson Barracks by solid dots.

and the deviation of the number of fruits from the number which would be expected if the number of capsules were proportional to the number of flowers formed throughout the entire range of variation of number of flowers per inflorescence.

The requisite formula has been given (Harris, '09a) and its range of applicability illustrated elsewhere (Harris, '18).

The results are given in the second correlation column of table XV. The values are low throughout. Eight are positive, while 2 are negative in sign. In general the coefficients are insignificant in comparison with their probable errors.

Taking these results as a whole, they indicate a slight relationship between the number of flowers per inflorescence and the capacity of the inflorescences for maturing their ovaries into fruits. Larger inflorescences mature on the average a slightly, but only slightly, larger proportion of their ovaries into fruits.

Turning to the literature for comparable cases, we note that in *Staphylea* (Harris, '09 a) and in *Crinum* (Harris, '12 a) inflorescences which produce larger numbers of flowers mature relatively smaller numbers of fruits. This is also the result announced by Reed for the lemon (Reed, '19). In *Celastrus* (Harris, '09) there is apparently no relationship between the number of flowers formed and the capacity of the inflorescence for maturing its ovaries into fruits.

### 3. THE RELATIONSHIP BETWEEN THE NUMBER OF FLOWERS PER INFLORESCENCE AND THE POSITION OF THE FRUITS

The foregoing analysis has shown that there is little relationship between the size of the inflorescence and the capacity for maturing its ovules into seeds.

We now have to consider another problem regarding fruit formation. This is: Has the size of the inflorescence as measured by the number of flowers which it produces an influence upon the position of the fruits which develop?

The problem of the relationship between the number of flowers and the position of the fruits which develop to maturity seems to be one of very real physiological interest. If we ignore for the moment the possible influence of the morphogenetic factor discussed above (p. 434) and look at the purely nutritional one, it seems reasonable to assume that development of fruit makes a certain demand upon the organism for plastic materials. If this demand is higher than the available supply in any case, it seems quite possible that the more proximal ovaries, which are the first to have their seeds fertilized, would develop into fruits in larger proportions, since they are in a position to make the first demand upon the plastic materials.

If, on the other hand, the organism is so exactly coordinated that the quantities of plastic materials available for the formation of fruits and seeds is proportional to the number of flowers formed,[1] one might expect that the position of the fruits would be little influenced by the number of flowers per inflorescence.

To solve this problem we may proceed in the following manner. We may determine the relation between the number of flowers per inflorescence and the position of the fruits which develop to maturity. In doing this we weight the number of flowers per inflorescence with the number of fruits produced, and consider the position of each fruit on the axis a deviation from the standard (proximal) position.[2] We must expect this relation to be large, since it is evident that on the average the fruits on large inflorescences, which produce more fruits, will be inserted higher than those which produce few fruits. It is possible, however, to determine the true physiological relationship between these 2 characters by the use of the formula measuring the relation between a variable and the deviation of a dependent variable from its probable value cited above. The position of any fruit must always represent some fraction, or component, of the maximum possible position on the inflorescence to which it belongs. This formula, therefore, seems quite applicable.

The correlation between the number of flowers per inflorescence and the position of the fruits on the inflorescence, and between the number of flowers on the inflorescence and the deviation of the position of the fruits from its probable position appear in table XVII.

[1] One may, if he chooses, look upon the number of flowers formed as very closely proportional to the quantities of plastic substances which are to be available for maturing these ovaries into fruit.

[2] The full data for the determination of these constants are rather too voluminous for publication here.

TABLE XVII

CORRELATION BETWEEN POSITION OF FRUITS ON THE INFLORESCENCE AND NUMBER OF FLOWERS PER INFLORESCENCE

| Series | Weighted N | Correlation between number of flowers and position of fruits | $\frac{r}{E_r}$ | Correlation, flowers per inflorescence and deviation of position of fruits from its probable position | $\frac{r}{E_r}$ |
|---|---|---|---|---|---|
| Meramec Highlands 1906 (I) | 2017 | .4151±.0322 | 12.89 | .0162±.0389 | 0.42 |
| Meramec Highlands 1907 (IV) | 1737 | .4605±.0307 | 15.00 | .0314±.0389 | 0.81 |
| Meramec Highlands 1907 (V) | 1849 | .4794±.0297 | 16.14 | .0216±.0386 | 0.56 |
| Meramec Highlands 1907 (IV)+(V) | 3586 | .4726±.0213 | 22.18 | .0291±.0274 | 1.06 |
| Jefferson Barracks 1906 (II) | 1120 | .4843±.0327 | 14.81 | −.0332±.0426 | 0.78 |
| Jefferson Barracks 1906 (III) | 5361 | .4266±.0174 | 24.51 | .0280±.0213 | 1.31 |
| Jefferson Barracks 1906 (II)+(III) | 6481 | .4328±.0155 | 27.92 | .0151±.0191 | 0.79 |
| Jefferson Barracks 1907 (VI) | 1392 | .4677±.0333 | 14.04 | .0536±.0425 | 1.26 |
| Jefferson Barracks 1907 (VII) | 6534 | .4344±.0171 | 25.40 | −.0151±.0211 | 0.72 |
| Jefferson Barracks 1907 (VI)+(VII) | 7926 | .4399±.0153 | 28.75 | −.0057±.0191 | 0.30 |

If there be no relationship between the number of flowers per inflorescence and the position of the fruits on the inflorescence, one should find a linear relationship between the average position of the fruits and the number of flowers per inflorescence. The equations to the straight lines in 4 of the series are:

Meramec Highlands, 1906, 300 inflorescences, 2017 fruits

$$p = -.554747 + .482806 f$$

Jefferson Barracks, 1906, 1250 inflorescences, 6481 fruits

$$p = -.400325 + .472802 f$$

Meramec Highlands, 1907, 605 inflorescences, 3586 fruits

$$p = -.857833 + .512934 f$$

Jefferson Barracks, 1907, 1270 inflorescences, 7926 fruits

$$p = +.160829 + .447496 f$$

The lines and empirical means for the 1906 series appear in fig. 8. The results indicate sensible linearity.

Turning to the problem of the correlation between number of flowers per inflorescence and deviation of position of fruits from its probable value, we note that the values are low throughout. They are generally smaller than their probable errors. Thus they indicate that the number of flowers per inflorescence has practically no influence on the position of the fruits which develop to maturity.

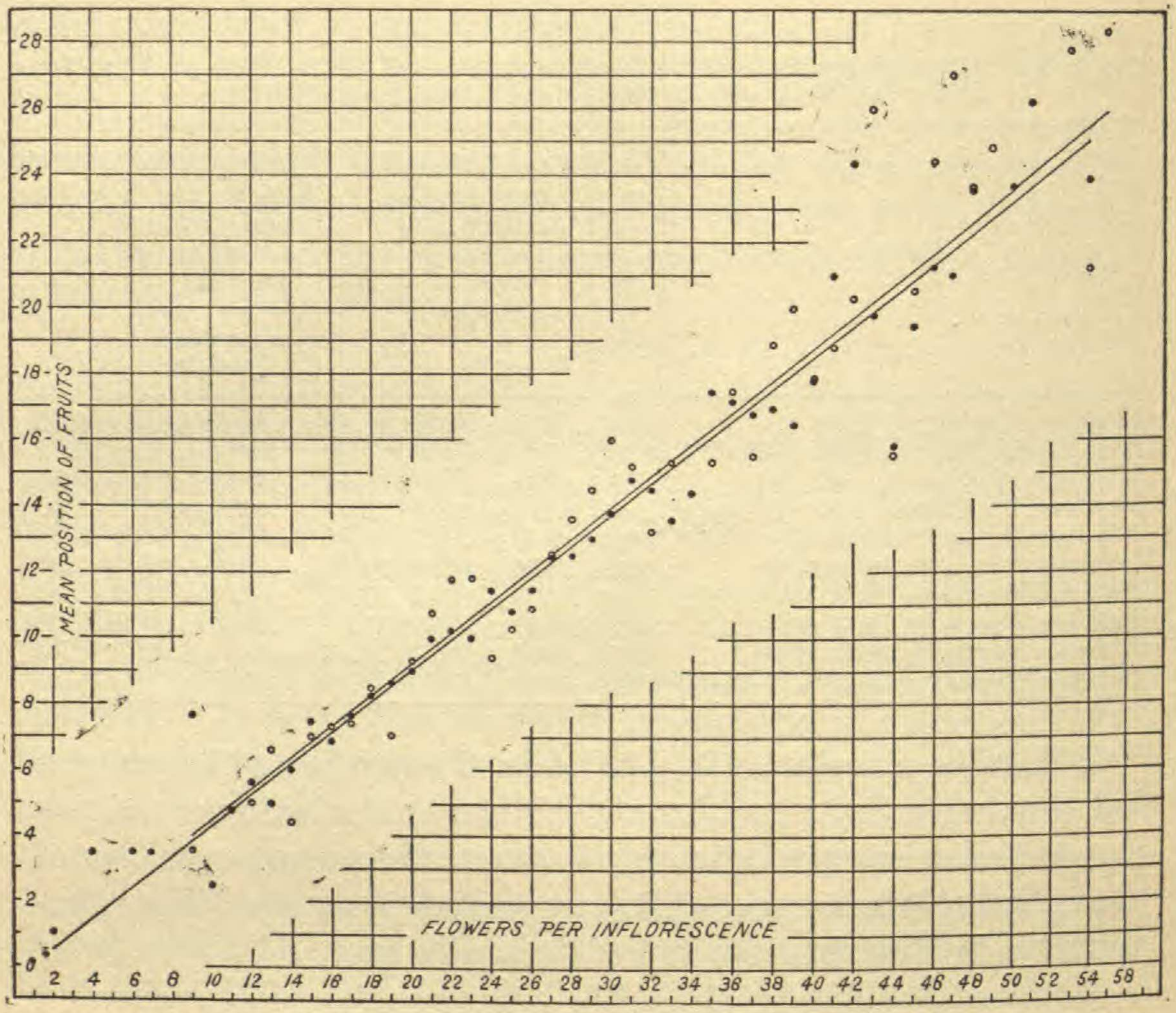


Fig. 8. Regression of position of fruits on number of flowers per inflorescence in 2 habitats for 1906. Upper line and circles = Meramec Highlands, lower line and solid dots = Jefferson Barracks.

In so far as they are pertinent to the problem, the constants in this table seem to show that the supply of fruit- and seed-forming substance is very nearly proportional to the number of flowers formed. These results are in full agreement with those of the preceding section (2) in which it was shown that there is little relationship between the number of flowers on the inflorescence and the capacity of the inflorescence for maturing these flowers into fruit.

### 4. THE RELATIONSHIP BETWEEN THE NUMBER OF FLOWERS AND FRUITS PER INFLORESCENCE AND THE NUMBER OF SEEDS PER LOCULE

We have, in this section, to consider the problem of the possible relationships between the size of the inflorescence as measured by the number of flowers and fruits which it produces and the fertility of its fruits.

This seems a question of very real physiological interest On *a priori* grounds one might be inclined to suggest that the size of the inflorescence is a measure of vigor, and that, as another expression of the greater vigor, larger numbers of seeds would be expected to be associated with larger numbers of flowers per inflorescence. On the other hand, it may be urged that since the inflorescences with larger numbers of flowers also produce larger numbers of fruits, the demands for plastic materials due to greater numbers of fruits would result in a reduction rather than in an increase in the number of seeds per locule.

The product moments for the relationship between the number of flowers per inflorescence and numbers of seeds per fruit may be calculated from table I.[1]

Table XVIII shows the correlation between the number of flowers per inflorescence and the number of seeds per locule and between the number of fruits per inflorescence and the number of seeds per locule in the 4 series in which the numbers of seeds were determined.

Three of the constants measuring the relationship between the number of flowers and the number of seeds are positive, while one is negative in sign. All are small, however, ranging from $-0.020$ to $+0.095$. In general the coefficients are not as large as their probable errors.[2]

Correlations between the number of fruits per inflorescence and

[1] Note that in determining the relationship between number of flowers and number of seeds the means and standard deviations for number of flowers per inflorescence must be redetermined by weighting with the number of fruits or number of locules per inflorescence. The constants thus weighted may be used in the determination of correlations for number of flowers and number of seeds per locule or seeds per fruit, since all of the fruits are trilocular.

[2] The question of the number to be used in calculating the probable error of these constants has presented considerable difficulty. The number of fruits in which the seeds were counted has been very large. If this $N$ were used in the determination of the probable error it would be very small indeed. It may be questioned, however, whether the probable error of the correlation between a weighted variable $x$ and another variable $y$ is any lower than that obtained when the unweighted number of the $x$ characters is used. We have, therefore, in determining these probable errors taken $N$ to be the actual number of inflorescences.

the number of seeds per locule may be deduced from the condensed correlation table appearing as table IV.[1]

The correlations between the number of fruits and the number of seeds per locule as given in table XVIII are negative in all 4 of the cases but are of a very low order, ranging from −0.043 to −0.127. Two of the 4 are over twice as large as their probable errors.

TABLE XVIII

CORRELATION BETWEEN FLOWERS PER INFLORESCENCE AND NUMBER OF SEEDS PER LOCULE AND BETWEEN NUMBER OF FRUITS PER INFLORESCENCE AND NUMBER OF SEEDS PER LOCULE

| Series | Flowers and seeds | $\frac{r}{E_r}$ | Fruits and seeds | $\frac{r}{E_r}$ | Difference | $\frac{\text{Diff.}}{E_{\text{diff.}}}$ |
|---|---|---|---|---|---|---|
| Meramec Highlands 1906 . . | +.0321±.0389 | 0.825 | −.0429±.0389 | 1.102 | −.0750±.0387 | 1.938 |
| Meramec Highlands 1907 . . | +.0382±.0388 | 0.985 | −.0569±.0388 | 1.466 | −.0951±.0387 | 2.457 |
| Difference. . . | +.0061±.0548 | 0.111 | −.0140±.0548 | 0.255 | ——— | — |
| Jefferson Barracks 1906 | +.0952±.0423 | 2.250 | −.0867±.0423 | 2.050 | −.1819±.0424 | 4.290 |
| Jefferson Barracks 1907 | −.0202±.0426 | 0.474 | −.1265±.0420 | 3.012 | −.1063±.0600 | 1.772 |
| Difference. . . | −.1154±.0600 | 1.923 | −.0398±.0600 | 0.663 | ——— | — |

These results show that unless there are statistical considerations which invalidate the coefficients of correlation as measures of interdependence in these cases, the relationship between the characteristics of the inflorescence and the number of seeds matured is very slight indeed. Apparently inflorescences which are initially large tend to have capsules with slightly larger numbers of seeds. Inflorescences which mature a large number of capsules tend to have a slightly smaller number of seeds in these capsules. The difference between the correlations for number of fruits and seeds and the number of flowers and seeds shows that in all 4

[1] The frequencies used in calculating the correlations given in this paper are slightly different from those shown here because of the fact that 10 locules in series IV and 14 locules in series VI had a questionable number of seeds. The difference in results obtained from calculations from this table and those actually used in obtaining our constants can hardly be significant, since they depend merely on differences due to 10 out of 5211 and 14 out of 4176 locules.

collections the relation between number of fruits and seeds is more strongly negative than that between number of flowers and seeds. At least 2 of these differences may be significant in comparison with their probable errors.

The correlation coefficients in these tables show that the relationship between the number of flowers per inflorescence and the number of seeds per locule and between the number of fruits per inflorescence and the number of seeds per locule is very slight indeed. How slender it is may be best shown by the use of straight-line equations. In these the variable term shows the actual increase or decrease in number of seeds per locule associated with an increase in the number of flowers per inflorescence or in the number of fruits per inflorescence. The equations are:

Meramec Highlands, 1906,

$$s = 12.9611 + .0250\,f, \quad s = 14.5414 - .0965\,c$$

Meramec Highlands, 1907,

$$s = 11.9176 + .0291\,f, \quad s = 13.7444 - .1335\,c$$

Jefferson Barracks, 1906,

$$s = 8.1589 + .0822\,f, \quad s = 11.5831 - .2173\,c$$

Jefferson Barracks, 1907,

$$s = 11.3520 - .0151\,f, \quad s = 12.6892 - .2585\,c$$

where $s$ = seeds, $f$ = flowers, and $c$ = fruits per inflorescence.

The lines and the empirical means are represented graphically for the relationship between number of flowers per inflorescence and number of seeds per locule in fig. 9, and for that between number of fruits per inflorescence and number of seeds per locule in fig. 10.

The mean numbers of seeds per locule are distributed with considerable irregularity about the nearly horizontal lines showing the theoretical change in mean number of seeds with variation in the number of flowers per inflorescence. There is, however, nothing in these lines to indicate that any single curve of a higher order would give a better representation of the relationship.

The lines and empirical means for number of seeds per locule of fruits produced on inflorescences with varying total numbers of fruits (fig. 10) may indicate a slightly non-linear distribution of

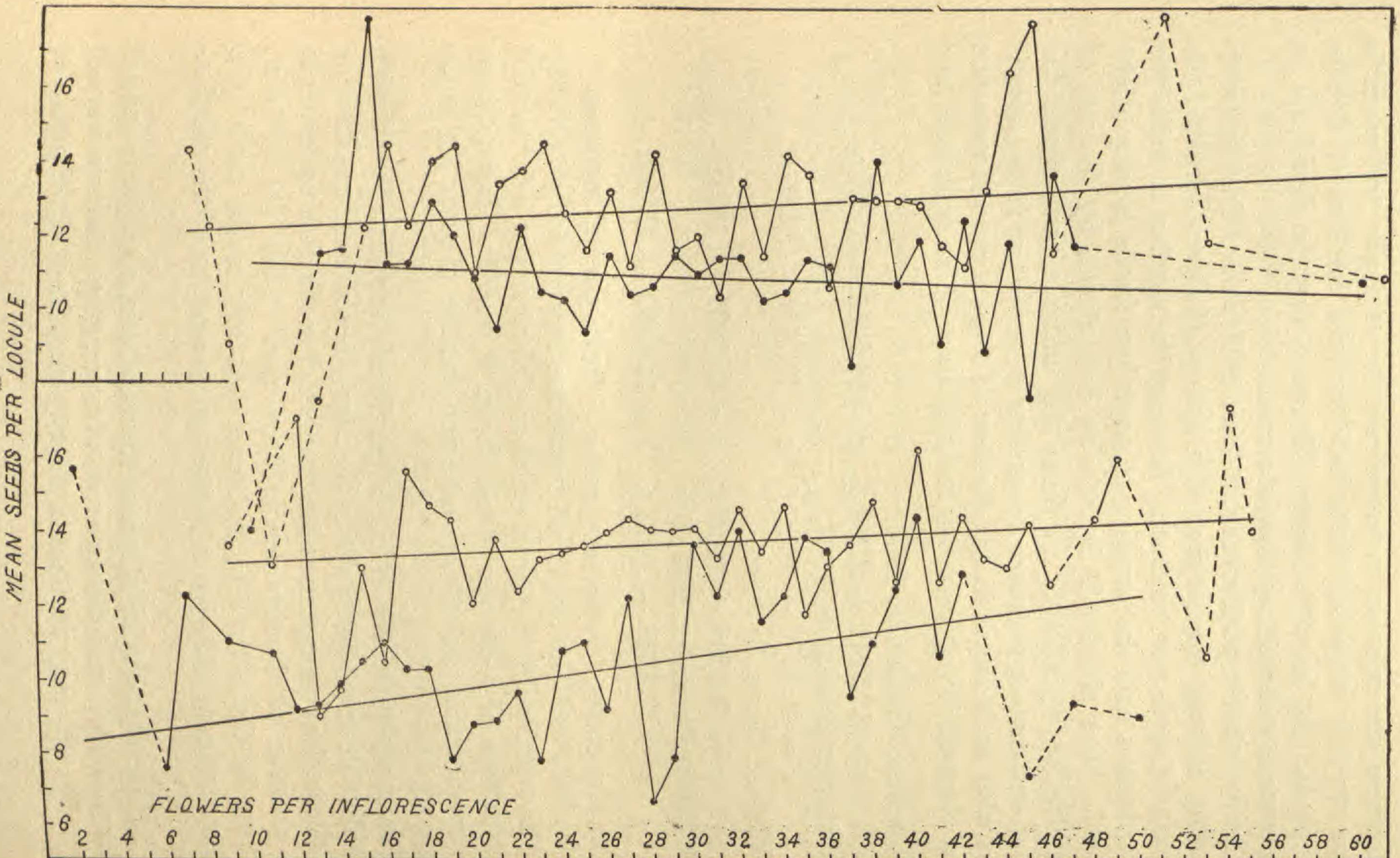


Fig. 9. Regression of number of seeds per locule on number of flowers per inflorescence. Circles represent empirical means for Meramec Highlands, solid dots those for Jefferson Barracks. Lower figure gives results for 1906, upper fiugre those for 1907.

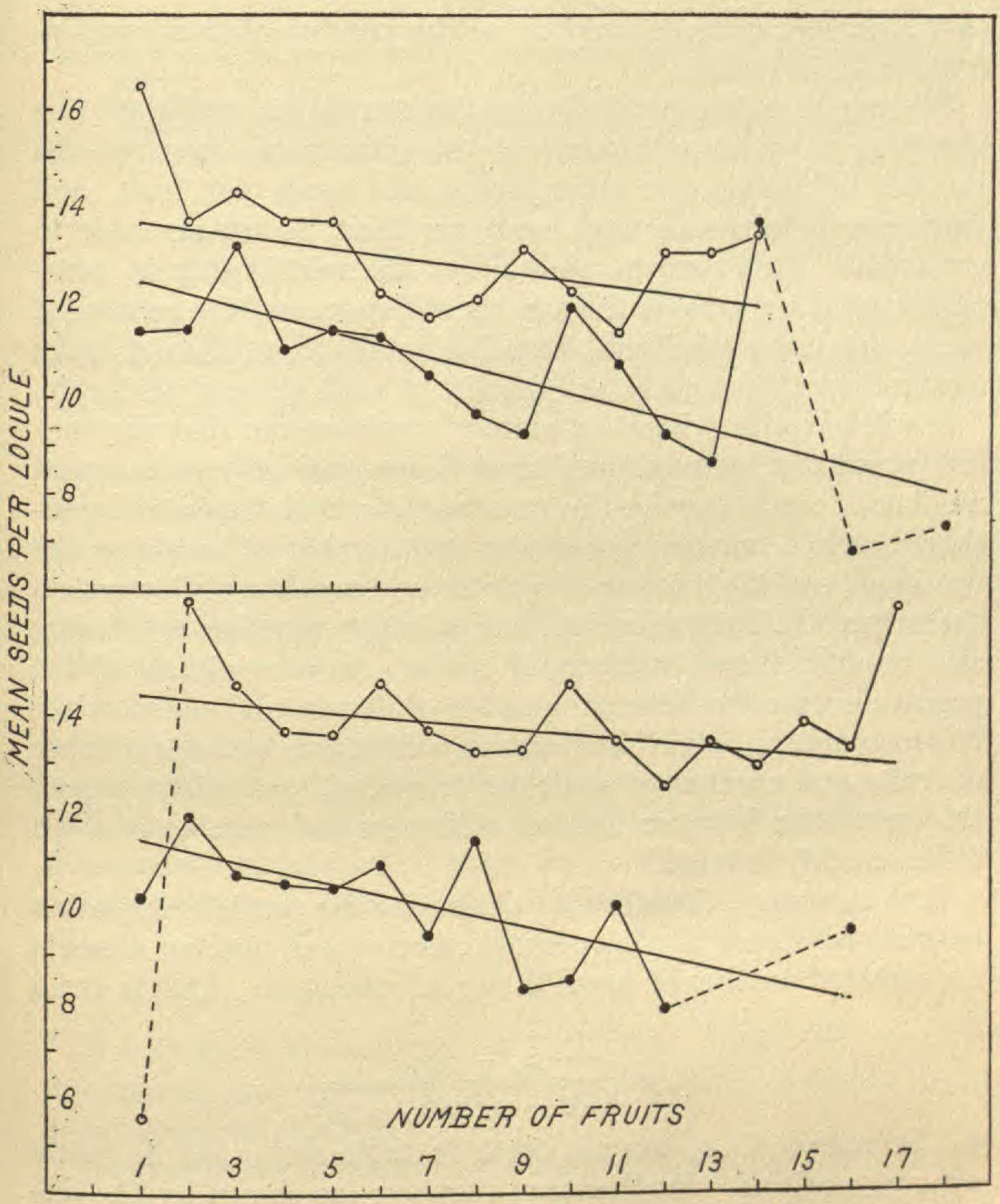


Fig. 10. Regression of number of seeds per locule on number of fruits per inflorescence. Circles represent empirical means for Meramec Highlands, solid dots those for Jefferson Barracks. Lower figure represents results for 1906, upper figure those for 1907.

the means.[1] They show, however, that there is a sensible decrease

[1] Further mathematical tests for non-linearity seem unadvisable because of the difficulties arising from the small frequencies in some of the classes, and because of the fact that the relationship between fruit and seed number is complicated by the relationship between flower and fruit number and flower and seed number, as shown in the following paragraphs.

in the number of seeds per fruit as the number of fruits per inflorescence increases.

We may therefore conclude that the correlation coefficient furnishes as adequate a measure of the relationship between the number of flowers per inflorescence and seeds per fruit, and fruits per inflorescence and seeds per fruit, as we are able to command. This measure shows that the relationship is, practically speaking, zero for the number of flowers and the number of seeds, but has a significant negative value for number of fruits matured per inflorescence and number of seeds ripened per locule.

It will be quite evident on mature consideration that the very low correlation between number of flowers per inflorescence and number of seeds may be the resultant of physiological relationships between number of capsules and number of seeds on the one hand, and the number of capsules and number of flowers, on the other. Inflorescences producing larger numbers of flowers also produce larger numbers of fruits. As a resultant of the positive correlation between number of flowers and capsules per inflorescence, $r_{fc}$, and of the negative correlation between number of fruits and number of seeds per locule, $r_{cs}$, one might expect the correlation between number of flowers and number of seeds to be sensibly lowered.[1]

It is necessary, therefore, to determine the partial correlation between number of flowers per inflorescence and number of seeds for constant number of capsules per inflorescence. This is given by

$$_{c}r_{fs} = \frac{r_{fs} - r_{fc}r_{cs}}{\sqrt{1 - r_{fc}^2}\sqrt{1 - r_{cs}^2}}$$

The values of $_{c}r_{fs}$ are set forth in table XIX. All 4 values are now positive. Furthermore they are (as shown by the difference column, $_{c}r_{fs} - r_{fs}$) larger than the uncorrected correlations.

Thus they indicate that if correction be made for the influence of the number of fruits whch mature, the inflorescences which are

[1] In inflorescences with larger numbers of fruits the plastic materials must be more extensively divided than in those with a small number of fruits. Number of fruits per inflorescence might, therefore, seem a more logical proximate cause of variation in the number of seeds matured than would number of flowers per inflorescence.

TABLE XIX

PARTIAL CORRELATION BETWEEN FLOWERS PER INFLORESCENCE AND SEEDS PER LOCULE FOR CONSTANT NUMBER OF FRUITS AND BETWEEN FRUITS AND SEEDS PER LOCULE FOR CONSTANT NUMBER OF FLOWERS PER INFLORESCENCE AND COMPARISON OF THE PARTIAL CORRELATIONS WITH THE GROSS CORRELATIONS

| Series | Partial correlation, flowers and seeds ${}_c r_{fs}$ | ${}_c r_{fs} - r_{fs}$ | Partial correlation, fruits and seeds ${}_f r_{cs}$ | ${}_f r_{cs} - r_{cs}$ |
|---|---|---|---|---|
| Meramec Highlands 1906 (I) | $+.0829 \pm .0387$ | $+.0508$ | $-.0875 \pm .0836$ | $-.0446$ |
| MeramecHighlands1907(IV) | $+.1003 \pm .0385$ | $+.0621$ | $-.1088 \pm .0385$ | $-.0519$ |
| Jefferson Barracks 1906 (II) | $+.1885 \pm .0411$ | $+.0932$ | $-.1844 \pm .0412$ | $-.0977$ |
| Jefferson Barracks 1907(VI) | $+.0565 \pm .0425$ | $+.0767$ | $-.1370 \pm .0419$ | $-.0105$ |

larger, as measured by the number of flowers which they produce, ripen slightly larger numbers of seeds per locule.

The reader will have noted that if the physiological relationship between size of inflorescence and number of seeds per locule be of a positive kind, such that (other factors being eliminated) larger inflorescences tend to mature larger numbers of seeds in their locules, this will tend to screen the true physiological relationship between the number of fruits matured per inflorescence and the number of seeds ripened per locule.

We therefore require the partial correlation between the number of capsules and number of seeds for constant number of flowers per inflorescence. The required formula is:

$$ {}_f r_{cs} = \frac{r_{cs} - r_{fc} r_{fs}}{\sqrt{1 - r_{fc}^2}\sqrt{1 - r_{fs}^2}} $$

The coefficients are given in table XIX. These are negative throughout, and all have a higher negative value than that of the uncorrected correlation.

Turning to the literature for comparable observations, we note that while data for size of inflorescence and number of seeds per fruit cannot be obtained in *Cercis*, we do have a series of ovaries (Harris, '12) in which the number of ovules was counted under the microscope. The correlations between the number of flowers per inflorescence and the number of ovules per ovary have been shown to be: For tree 1, $r = -.007 \pm .023$; for tree 2, $r = +.030 \pm .021$; for tree 3, $r = +.134 \pm .024$. These constants are so low that their significance is questionable.

In *Celastrus* (Harris, '09) the correlation between both number of flowers and number of fruits per inflorescence, on the one hand, and number of seeds per fruit, on the other, are very low. The actual constants are:

For number of flowers and number of seeds, $r = + .033 \pm .013$.

For number of fruits and number of seeds, $r = - .012 \pm .013$.

The inflorescence and fruit of *Staphylea* has been rather exhaustively studied. It has been shown (Harris, '12b) that the average values of the correlation coefficients for a series of 20 shrubs studied at the Missouri Botanical Garden in 1906 are:

For fruits per inflorescence and ovules per locule,

$$r = .0192 \pm .0185.$$

For fruits per inflorescence and seeds per locule,

$$r = - .0399 \pm .0080.$$

For general samples of fruits, comprising the collections from all the shrubs, the correlations have been shown to be:

| Year of collection | Number of locules | Fruits and ovules, $r_{fo}$ | Fruits and seeds, $r_{fs}$ |
|---|---|---|---|
| 1906 | 6177 | $+.0391 \pm .0086$ | $-.0474 \pm .0086$ |
| 1908 | 12099 | $+.0633 \pm .0061$ | $-.0494 \pm .0061$ |
| 1909 | 6246 | $-.0539 \pm .0085$ | $+.0626 \pm .0085$ |

Two of the coefficients are negative. The correlation between the number of fruits per inflorescence and length of fruit in *Staphylea* has been found (Harris, '12) to be of the order $r = - .1828 \pm .0144$.

For *Crinum longifolium* (Harris, '12 a) the correlation between the number of fruits per inflorescence and number of seeds per fruit is $r = - .072 \pm .024$.

### 5. THE RELATIONSHIP BETWEEN THE ACTUAL AND THE RELATIVE POSITION OF THE FRUIT ON THE INFLORESCENCE AND THE NUMBER OF SEEDS PRODUCED

The proportion of the ovaries which develop into fruits at different positions on the inflorescence axis has already been discussed (p. 425).

In considering the influence of position on the inflorescence upon the development of the fruit, the only measure of position which requires consideration is that furnished by the position of the flower. When we turn to the problem of the influence of position upon the development of the seed, it is clear that either the position of the flower on the axis or the position of the matured fruits in the series of fruits may be taken as a measure of position. Position in the latter case may be either the actual position which the matured ovary occupies in the series of flowers on the inflorescence or it may be the position which a fruit occupies in the series of fruits matured. For example, if the third flower from the proximal end of the inflorescence develops into a fruit it will be recorded as occupying the third position in the series of flowers. But if the first 2 flowers fail to develop it will occupy the first position in the series of fruits.

The first of these may be designated as the actual position of the fruit, the second as the relative position of the fruit.[1]

The total number of flowers, the total number of fruits, and the total number of seeds produced at each (actual) position on the inflorescence are shown for the 4 series of materials in which the number of seeds was determined in table x. From this table the correlations between actual position and number of seeds per locule, set forth in table xx, have been deduced.

The correlation between the relative position of the fruit and number of seeds per locule or per fruit may be deduced from the condensed correlation table xxi, in which the position of the fruit, the number of locules, and total number of seeds produced by those locules are shown for the 4 series of material in which number of seeds was determined.[2]

The relationship between the actual position of the fruit and the number of seeds matured per locule and that between the relative position of the fruit and the number of seeds matured per locule are laid side by side in table xx. These coefficients are, without exception, negative in sign. Thus the number of seeds

[1] Since in correlations between position on the inflorescence and number of seeds per locule or per fruit the position must be weighted with the number of fruits counted, the weighted constants are necessary. These may be deduced from the tables of data, but, since they are needed only for the correlations, are not tabled here.

[2] The correlation between the relative position and total seeds per fruit may be determined from this table by substituting the number of fruits for the number of locules and the means and the standard deviations of number of seeds per fruit for number of seeds per locule.

TABLE XX

CORRELATION BETWEEN THE ACTUAL POSITION OF THE FRUIT AND NUMBER OF SEEDS PER LOCULE AND BETWEEN THE RELATIVE POSITION OF THE FRUIT AND NUMBER OF SEEDS PER LOCULE

| Series | Actual position and seeds | $\frac{r}{E_r}$ | Relative position and seeds | $\frac{r}{E_r}$ | Difference | $\frac{\text{Diff.}}{E_{\text{diff.}}}$ |
|---|---|---|---|---|---|---|
| Meramec Highlands 1906 . . | −.0778±.0387 | 2.010 | −.0541±.0388 | 1.394 | +.0237±.0548 | 0.432 |
| Meramec Highlands 1907 . . | −.1129±.0384 | 2.940 | −.0500±.0388 | 1.288 | +.0629±.0539 | 1.167 |
| Difference. . . | −.0351±.0539 | 0.651 | +.0041±.0548 | 0.075 | — | — |
| Jefferson Barracks 1906 | −.1147±.0420 | 2.730 | −.1232±.0420 | 2.933 | −.0085±.0592 | 0.143 |
| Jefferson Barracks 1907 | −.1229±.0420 | 2.926 | −.1040±.0421 | 2.470 | +.0189±.0592 | 0.319 |
| Difference . . | −.0082±.0592 | 0.139 | +.0192±.0592 | 0.324 | — | — |

TABLE XXI

NUMBER OF LOCULES AND TOTAL SEEDS AT VARIOUS RELATIVE POSITIONS ON THE INFLORESCENCE IN 4 SERIES IN WHICH NUMBER OF SEEDS WAS DETERMINED

| Relative position | J. B. 1906 | | J. B. 1907 | | M. H. 1906 | | M. H. 1907 | |
|---|---|---|---|---|---|---|---|---|
| | Locules | Total seeds | Locules | Total seeds | Locules | Total seeds | Locules | Total seeds |
| 1 | 744 | 8267 | 747 | 8313 | 897 | 12278 | 891 | 11134 |
| 2 | 702 | 7671 | 731 | 8673 | 894 | 12641 | 869 | 11973 |
| 3 | 600 | 6153 | 687 | 7659 | 864 | 12553 | 833 | 11055 |
| 4 | 435 | 4568 | 582 | 6462 | 795 | 11051 | 711 | 9374 |
| 5 | 297 | 2757 | 453 | 5068 | 687 | 9392 | 558 | 6753 |
| 6 | 204 | 1948 | 326 | 3243 | 552 | 7527 | 448 | 5391 |
| 7 | 141 | 1395 | 222 | 2182 | 411 | 5577 | 318 | 3711 |
| 8 | 96 | 816 | 138 | 1243 | 333 | 4400 | 219 | 2836 |
| 9 | 60 | 551 | 96 | 953 | 231 | 2982 | 144 | 1767 |
| 10 | 42 | 239 | 66 | 612 | 153 | 1934 | 84 | 980 |
| 11 | 18 | 146 | 45 | 348 | 108 | 1437 | 57 | 722 |
| 12 | 9 | 71 | 27 | 251 | 63 | 789 | 45 | 551 |
| 13 | 3 | 11 | 15 | 103 | 30 | 393 | 18 | 248 |
| 14 | 3 | 1 | 9 | 111 | 15 | 142 | 6 | 59 |
| 15 | 3 | 16 | 6 | 16 | 9 | 150 | — | — |
| 16 | 3 | 1 | 6 | 109 | 6 | 68 | — | — |
| 17 | — | — | 3 | 37 | 3 | 13 | — | — |
| 18 | — | — | 3 | 15 | — | — | — | — |

matured in the more distal position is smaller than that in the more proximal position. The differences between the correlations for the same habitat for the 2 years cannot be considered significant in comparison with their probable errors. The correlations are, however, of a very low order. Those for actual position and the number of seeds range from — 0.078 to — 0.123. Those for relative position and number of seeds range from — 0.050 to — 0.123. A comparison of the correlations between

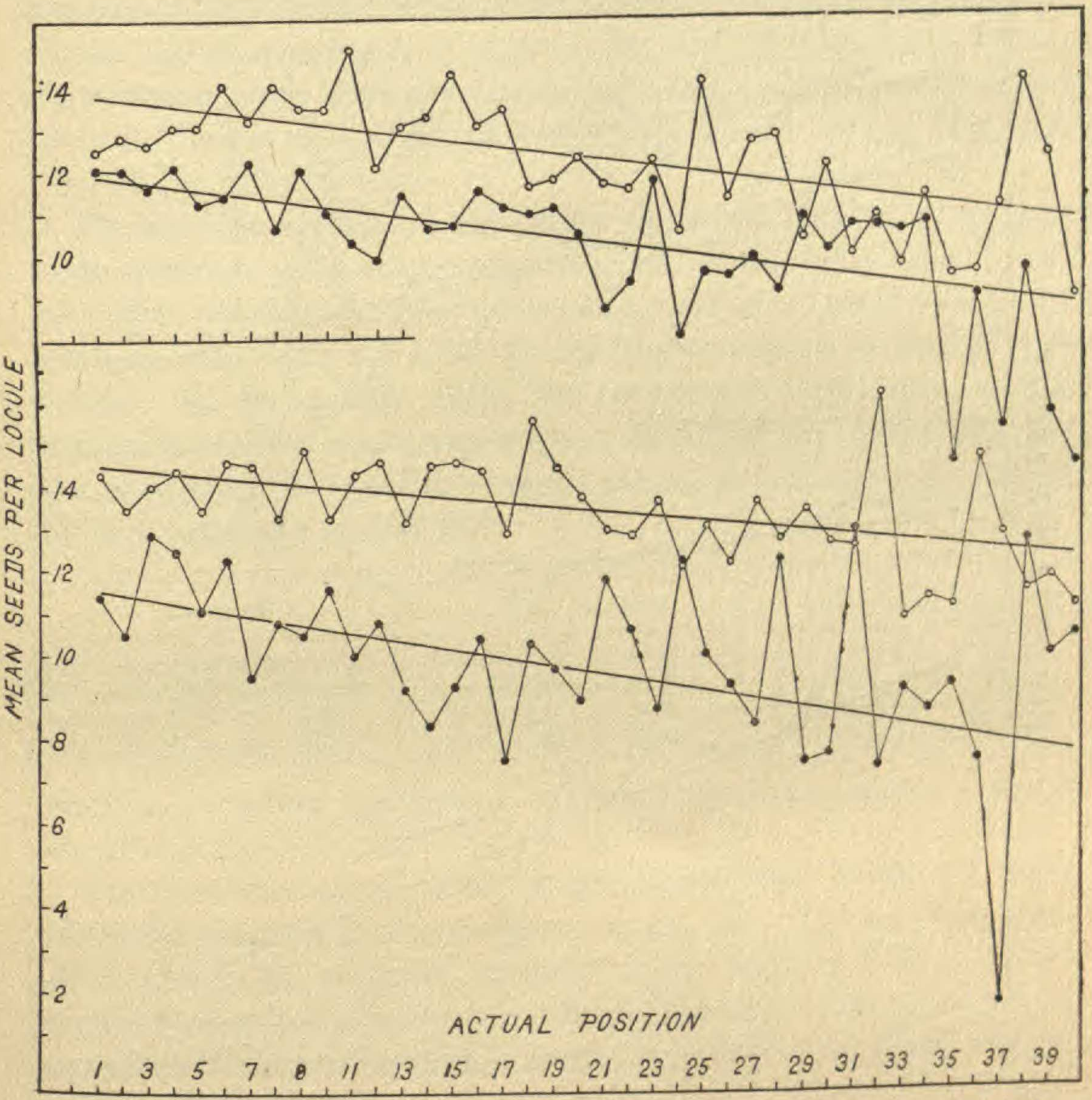


Fig. 11. Regression of number of seeds per locule on actual position of the fruit. Circles = Meramec Highlands, solid dots = Jefferson Barracks. The lower figure gives the results for 1906, the upper figure those for 1907.

the relative position and number of seeds, and actual position and number of seeds shows that in one case the former and in 3 cases the latter is the larger. No one of these differences is significant in comparison with the probable error of the determination. Thus it is impossible to assert on the basis of the materials now

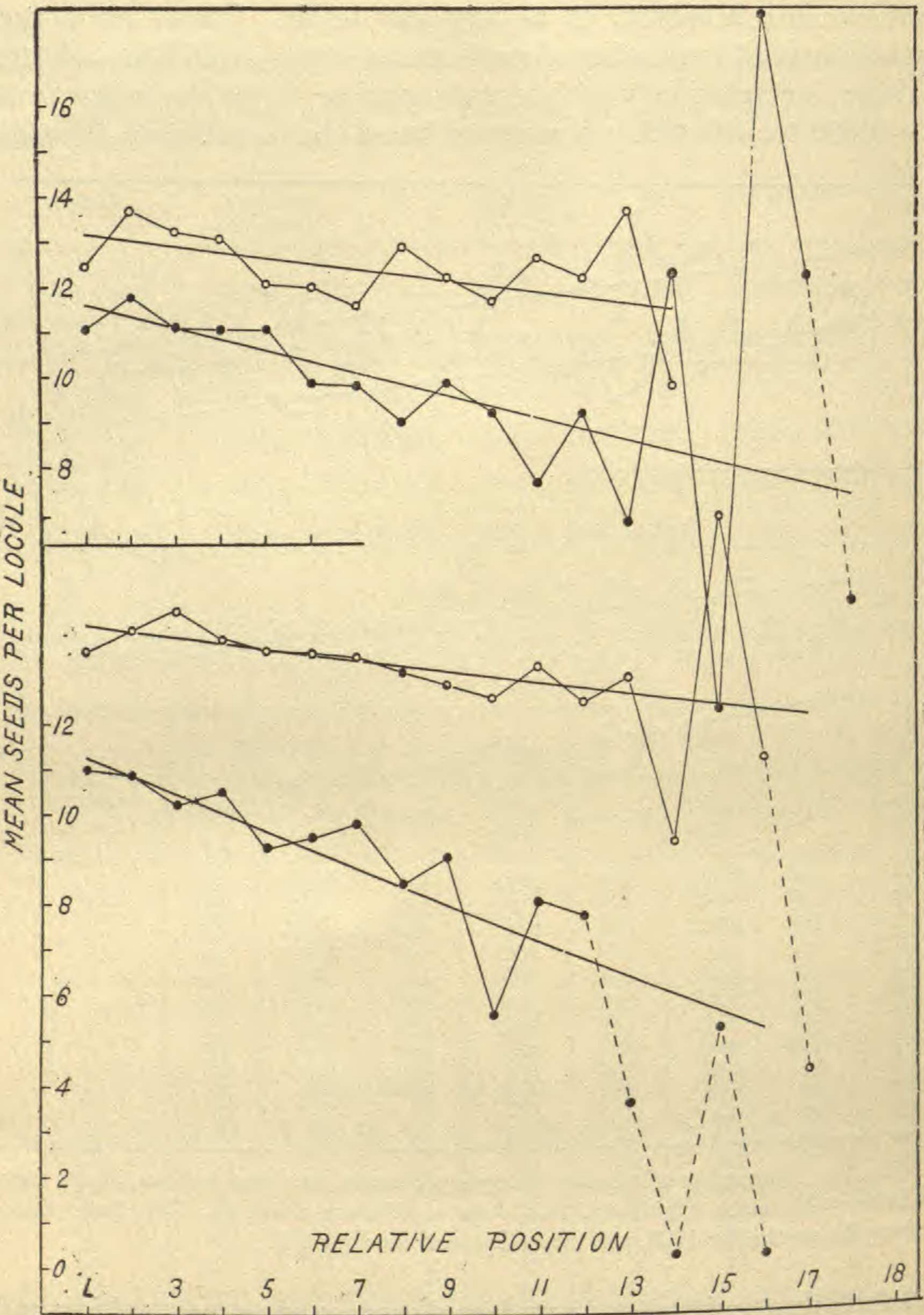


Fig. 12. Regression of number of seeds per locule on relative position of the fruit. Circles = empirical means for Meramec Highlands, solid dots = empirical means for Jefferson Barracks. Lower figure gives results for 1906, upper figure for 1907.

available that one of these relationships is more intimate than the other.

The low correlations between the actual position and the relative position of the fruit and the number of seeds which it produces may be due either to an absence of relationship between these two characters or it may be due to a periodicity in the inflorescence, such that the number of seeds at first increases and then decreases as one passes from the proximal toward the distal end of the inflorescence.

To test this matter we determine the mean number of seeds in each position, both actual and relative, on the inflorescence, and ascertain whether the change in mean number of seeds occurs at a uniform rate from the lower to the higher regions of the inflorescence. To be strictly valid the correlation coefficients should represent cases of linear regression. The linear equations showing the change in the number of seeds per locule with position on the inflorescence are as follows:

| | Actual position | Relative position |
|---|---|---|
| Meramec Highlands, 1906 | $s = 14.5551 - .0519\, a$ | $s = 14.3458 - .1280\, r$ |
| Meramec Highlands, 1907 | $s = 13.9185 - .0787\, a$ | $s = 13.3141 - .1279\, r$ |
| Jefferson Barracks, 1906 | $s = 11.6245 - .0980\, a$ | $s = 11.6010 - .3769\, r$ |
| Jefferson Barracks, 1907 | $s = 12.0439 - .0850\, a$ | $s = 11.8913 - .2491\, r$ |

Here $a$ = actual position, $r$ = relative position, and $s$ = number of seeds per locule.

The lines for actual position are represented in fig. 11, while those for relative position appear in fig. 12. For both relationships and in all series of material these indicate a uniform decrease in number of seeds per inflorescence when the capsules are considered in series ranging from the proximal to the distal regions of the inflorescence.

For comparison we have a number of determinations on the inflorescence of *Staphylea*, in which the relationship between position and number of ovules (Harris, '11 a) and between position and number of seeds (Harris, '12 b) have been shown to be very small numerically but generally negative in sign. The relationship between position on the inflorescence and length of pod in *Staphylea* has also been shown (Harris, '12) to be slightly negative.

## 6. THE RELATIONSHIP BETWEEN THE NUMBER OF SEEDS IN THE LOCULES OF THE SAME FRUIT

The correlations between the number of flowers and fruits per inflorescence and the actual and relative position of the fruit on the inflorescence, on the one hand, and the number of seeds per locule, on the other, have been shown to be of a very low order indeed. We cannot, therefore, regard any of these earlier established characters, or the factors which determine them, as having a large influence in determining the number of seeds per locule.

Having failed to locate factors of material importance in the characters of the inflorescence, we may inquire whether there are unmeasurable factors which influence all of the locules of the same fruit in a similar manner.

This may be done by determining the inter-locular relationship for number of seeds per locule in the different series. In doing this, symmetrical tables are formed. The number of seeds in each locule is considered a first and then a second member of the pair in combination with the other locules of the fruit. The values of the correlation coefficients were checked by the use of the intra-class correlation formulae (Harris, '13).

The tables of data are too voluminous for publication.

The correlation coefficients and the regression equations are set forth in table XXII and show a high degree of similarity between numbers of seeds in the locules of the same fruit. The correlation lies between 0.70 and 0.80. Since the tables are symmetrical, the correlation and the regression coefficients are identical. The straight lines and the empirical means for the materials for the 2 pairs of years are shown in fig. 13. Apparently the straight line represents the relationship between the observed and the theoretical average as well as would any curve of higher order. The closely contiguous position of the lines for the years shows the generality of the laws underlying the interdependence between seed number in the 3 locules of the fruit.

Comparable determinations for other species are few in number. In *Sanguinaria* (Harris, '10) the correlations for number of ovules on the 2 placentae have been shown to be of the order $r = .89$ to $r = .92$, while the correlations for number of seeds per locule

TABLE XXII

CORRELATION BETWEEN NUMBER OF SEEDS PER LOCULE IN THE SAME FRUIT AND REGRESSION EQUATIONS SHOWING THE RELATION BETWEEN THE NUMBER OF SEEDS IN THE LOCULE OF THE FRUIT

| Series | Weighted N | Correlation | Regression equation |
|---|---|---|---|
| Jefferson Barracks 1906 | 6720 | .7901 ± .0044 | $l_2 = 2.1619 + .7901\, l_1$ |
| Meramec Highlands 1906 | 12102 | .7119 ± .0043 | $l_2 = 3.9669 + .7119\, l_1$ |
| Jefferson Barracks 1907 | 8274 | .7408 ± .0047 | $l_2 = 2.8374 + .7408\, l_1$ |
| Meramec Highlands 1907 | 10374 | .7383 ± .0042 | $l_2 = 3.3479 + .7383\, l_1$ |

have a value of $r = .80$ to $r = .84$. That the correlation for seed production is not due solely to the high correlation of the numbers of ovules on the 2 placentae is shown by the fact that the partial correlations between the numbers of seeds on the 2 placentae for constant numbers of ovules have a material value.

In *Hibiscus* (Harris, '13) it has been shown that for 1000 fruits examined at the Missouri Botanical Garden in the fall of 1905 the intra-ovarial correlations were

For ovules per locule, $r = .3843 \pm .0081$
For seeds per locule, $r = .5557 \pm .0066$

Excess for seeds $.1714 \pm .0104$

Here again the results indicate distinct physiological factors influencing the capacities of the several locules of the fruit for seed production in such a way as to bring about a similarity between them.

In *Crinum longifolium* a correlation of $r = .676 \pm .008$ has been demonstrated (Harris, '12 a) between the weight of the seeds from the same fruit.

All these results agree in indicating that there are morphogenetic or physiological factors tending to bring about a similarity in the seed production and in the seed weight of the locules of the fruit.

## IV. Recapitulation and Discussion

This paper has had for its purpose the consideration of various problems of fertility in *Manfreda virginica* (*Agave virginica*). The conclusions are based on the statistical analysis of extensive series

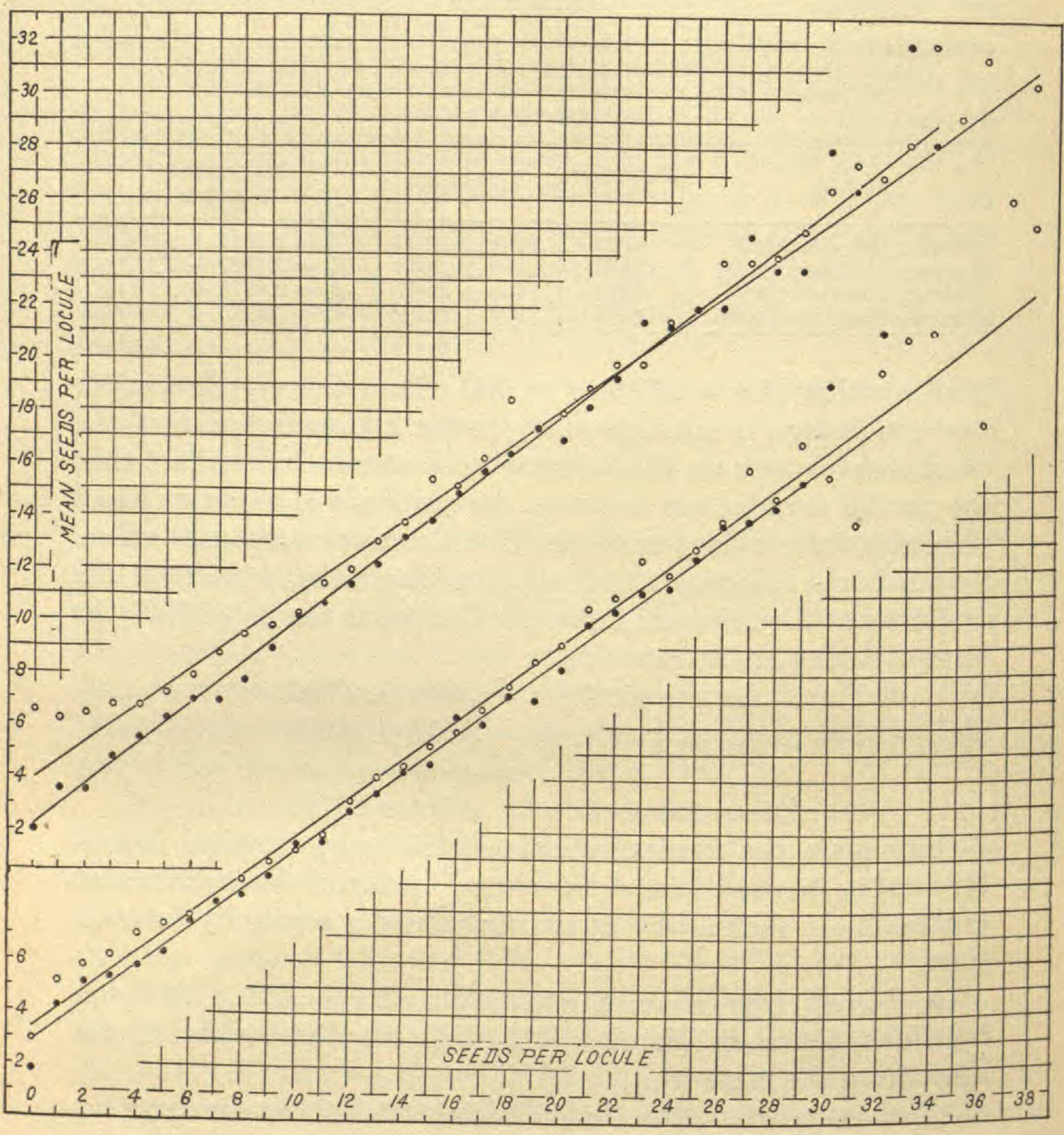


Fig. 13. Regression of number of seeds in the locule of the fruit on number of seeds in another locule of the same fruit. Circles = Meramec Highlands, solid dots = Jefferson Barracks. In both figures the upper lines (at the beginning) represent the equations for the Meramec Highlands series. Lower figure represent series for 1907, upper figure represents series for 1906.

of countings made at Meramec Highlands and Jefferson Barracks, near St. Louis, Mo., in 1906 and 1907. Briefly stated, the results are as follows:

1. The average number and the variation in number of flowers and fruits per inflorescence and seeds per locule in the two habitats and years has been determined, and compared with the available data for fertility in other species. For details reference must be made to the body of the paper.

2. About 22 per cent of the flowers develop their ovaries into fruits. The correlation between the number of flowers formed and the number of fruits matured is of about medium value. This is, however, due to the fact that as the result of chance only the larger inflorescences should produce larger numbers of fruits. A special formula shows that there is little relationship between the size of the inflorescence as measured by the number of flowers which it produces and its capacity for maturing its ovaries into fruits.

3. While the more proximal and more distal flowers on the inflorescence show a smaller proportion of fruit production, there is little relationship between the size of the inflorescence as measured by the number of flowers produced and the position of the flowers which mature their ovaries into fruits.

4. There is practically speaking no correlation between the number of flowers on the inflorescence and the number of seeds matured per locule. This is apparently in part due to the negative correlation between the number of fruits matured and number of seeds per locule. If correction for the number of fruits be made it is shown that the inflorescences which produce the larger numbers of flowers also mature slightly larger numbers of seeds per locule.

5. There is a slight negative correlation between the number of fruits ripened per inflorescence and the number of seeds matured per locule.

The physiological significance of (4) and (5) is considered.

6. The fertility of the fruits tends to decrease slightly, and approximately uniformly, from the proximal to the distal end of the inflorescence.

7. While there is little relationship between number of flowers or number of fruits per inflorescence or position on the inflorescence and the number of seeds per locule, the correlation between the number of seeds in the 3 locules of the fruit is high. Thus

there are as yet unmeasurable factors which influence in a similar manner the seed production of the 3 locules of the same ovary. These may be in part ecological, depending upon accidents of fertilization, and in part physiological.

The result of greatest importance derived from this investigation is the generally low correlation between the meristic characters of the inflorescence and fruit and seed production. While variation in seed production is clearly the resultant of underlying causes, these "causes" are not easily located in the variations of the magnitudes of any of the antecedently formed structures. Thus there is little relationship between the number of flowers formed per inflorescence and the number of seeds matured per locule. This conclusion, that there is but a low correlation between somatic characters and fertility, is in full agreement with those drawn from a consideration of the relationship between the number of parts of the involucral whorl and fertility in *Hibiscus* (Harris, '11).

This conclusion is not shaken by the more substantial correlations formed between number of pods and number of ovules and seeds in *Phaseolus* (Harris, '14), for here, as in *Sanguinaria* (Harris, '10) and in *Nothoscordum* and *Allium* (Harris, '09 b), we have questions of possible age differentiation in the perennials or of the somatic character measured standing more directly in relation to the fertility characters as means of support, conducting tracts for plastic materials, or as an actual source of the elaboration of plastic materials.

## Literature Cited

Harris, J. Arthur ('09). Correlation in the inflorescence of *Celastrus scandens*. Mo. Bot. Gard., Ann. Rept. **20:** 116–122. 1909.

————, ('09 a). The correlation between a variable and the deviation of a dependent variable from its probable value. Biometrika **6:** 438–443. 1909.

————, ('09 b). Correlation between length of flowering stalk and number of flowers per inflorescence in Nothoscordum and Allium. Mo. Bot. Gard., Ann. Rept. **20:** 105–115. 1909.

————, ('10). A quantitative study of the morphology of the fruit of the bloodroot, Sanguinaria canadensis. Biometrika **7:** 305–351. *f. 1.* 1910.

————, ('11). On the correlation between somatic characters and fertility: Illustrations from the involucral whorl of Hibiscus. *Ibid.* **8:** 52–65. *f. 1–5.* 1911.

————, ('11 a). Further observations on the selective elimination of ovaries in Staphylea. Zeitschr. f. ind. Abst. u. Vererbungsl. **5**: 173–188. 1911.

————, ('12). The influence of the seed upon the size of the fruit in Staphylea. II. Bot. Gaz. **53**: 396–414. 1912.

————, ('12 a). Biometric data on the inflorescence and fruit of Crinum longifolium. Mo. Bot. Gard., Ann. Rept. **23**: 75–99. 1912.

————, ('12 b). Observations on the physiology of seed development in Staphylea. Beih. Bot. Centralbl. **28**[1]: 1–16. 1912.

————, ('13). On the calculation of intra-class and inter-class coefficients of correlation from class moments when the number of possible combinations is large. Biometrika **9**: 446–472. 1913.

————, ('14). On the correlation between somatic characters and fertility. II. Illustrations from Phaseolus vulgaris. Am. Jour. Bot. **1**: 398–411. 1914.

————, ('18). Further illustrations of applicability of a coefficient measuring the correlation between a variable and the deviation of a dependent variable from its probable value. Genetics **3**: 328–352. 1918.

Reed, H. S. ('19). Certain relationships between the flowers and fruits of the lemon. Jour. Agr. Res. **17**: 153–165. 1919.